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## *Abstracts of recently accepted papers*

### **The pre-main sequence spectroscopic binary AK Sco revisited**

**S.H.P. Alencar<sup>1,2</sup>, C.H.F. Melo<sup>3</sup>, C.P. Dullemond<sup>4</sup>, J. Andersen<sup>5</sup>, C. Batalha<sup>6</sup>, L.P.R. Vaz<sup>1</sup>, and R.D. Mathieu<sup>7</sup>**

<sup>1</sup> Departamento de Física, ICEx-UFMG, CP. 702, Belo Horizonte - MG, 30123-970, Brazil

<sup>2</sup> Departamento de Astronomia, IAG, USP, Rua do Matão, 1226, São Paulo, 05508-900, Brazil

<sup>3</sup> European Southern Observatory, Casilla 19001, Santiago 19, Chile

<sup>4</sup> Max Planck Institut für Astrophysik, Postfach 1317, D-85741 Garching, Germany

<sup>5</sup> Niels Bohr Institute for Astronomy, Physics, and Geophysics, Astronomical Observatory, Juliane Maries Vej 30, 2100 Copenhagen, Denmark

<sup>6</sup> Observatório Nacional, Departamento de Astrofísica, Rua General José Cristino 77, São Cristóvão, Rio de Janeiro, 20921-400, Brazil

<sup>7</sup> Department of Astronomy, University of Wisconsin-Madison, 475 North Charter Street, Madison, WI, 53706, USA

E-mail contact: [silvia@fisica.ufmg.br](mailto:silvia@fisica.ufmg.br)

We present an analysis of 32 high-resolution echelle spectra of the pre-main sequence spectroscopic binary AK Sco obtained during 1998 and 2000, as well as a total of 72 photoelectric radial-velocity observations from the period 1986-1994. These data allow considerable improvement of the period and other orbital parameters of AK Sco. Our analysis also includes eight series of photometric observations in the *uvby* and Geneva seven-color systems from 1987, 1989, 1990, 1992, 1994 and 1997. No eclipses or other periodic variations are seen in the photometry, but the well-determined HIPPARCOS parallax allows us to constrain the orbital inclination of the system to the range  $65^\circ < i < 70^\circ$ , leading to the following physical parameters for the two near-identical stars:  $M = 1.35 \pm 0.07 M_\odot$ ,  $R = 1.59 \pm 0.35 R_\odot$ , and  $v \sin i = 18.5 \pm 1.0 \text{ km s}^{-1}$ .

Disk models have been fit to the spectral energy distribution of AK Sco from 350 nm to 1100  $\mu\text{m}$ . The above stellar parameters permit a consistent solution with an inner rim temperature of 1250 K, instead of the usual 1500 K corresponding to the dust evaporation temperature. Dynamical effects due to tidal interaction of the binary system are supposed to be responsible for pushing the inner disk radius outwards. Combining simultaneous photometric and spectroscopic data sets allows us to compute the dust obscuration in front of each star at several points over the orbit. The results demonstrate the existence of substructure at scales of just a single stellar diameter, and also that one side of the orbit is more heavily obscured than the other.

The spectrum of AK Sco exhibits emission and absorption lines that show substantial variety and variability in shape. The accretion-related lines may show both outflow and infall signatures. The system displays variations at the binary orbital period in both the photospheric and accretion-related line intensities and equivalent widths, although with appreciable scatter. The periodic variations in the blue and red wing of  $H\beta$  are almost  $180^\circ$  out of phase.

We find no evidence of enhanced accretion near the periastron passage in AK Sco as expected theoretically and observed previously in DQ Tau, a similarly young binary system with a mass ratio near unity and an eccentric orbit. The  $H\alpha$  equivalent width displays rather smooth variations at the stellar period, peaking around phases 0.6-0.7, far away from periastron where theory expects the maximum accretion rate to occur.

Accepted by A&A

Preprints available to download at [www.fisica.ufmg.br/~silvia/papers.html](http://www.fisica.ufmg.br/~silvia/papers.html)

## Two Embedded Young Stellar Objects in NGC 2264 with FU Orionis Characteristics

Colin Aspin<sup>1</sup> & Bo Reipurth<sup>2</sup>

<sup>1</sup> Gemini Observatory, 670 N Aohoku Pl., Hilo, HI 96720, USA

<sup>2</sup> Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822, USA

E-mail contact: caa@gemini.edu

We report the discovery of two young stars in the NGC 2264 star forming molecular cloud whose physical and morphological characteristics are similar to FU Orionis objects. The objects form a close pair and exhibit a curved reflection nebula in the near-IR. The brighter of the two stars, AR 6A, is optically visible but considerably reddened, has a small 3  $\mu\text{m}$  IR excess, shows pronounced 2.294  $\mu\text{m}$  CO overtone bandhead absorption, and is the brightest near-IR object in the region. The fainter star, AR 6B, located 2.8'' South, has a much larger thermal IR excess and shows considerably deeper CO bandhead absorption identical to that seen in several known FUors. Both stars therefore resemble FUors in terms of thermal excess, near-IR spectral features, and morphology. Here, we discuss the characteristics of AR 6A and AR 6B in relation to the FUor population and propose that both stars are likely additional member of this class of young stellar outburst objects. We speculate that the simultaneous appearance of two FUor-like objects in a binary system, which would be highly unlikely if unrelated, could be caused by orbital evolution in a newly formed hierarchical quadruple system.

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Preprint at <http://ftp.gemini.edu/staff/caa/ngc2264.ps.gz>

## Rapid Formation of Outer Giant Planets by Disk Instability

Alan P. Boss

DTM, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015-1305, USA

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

The formation mechanism of the ice giant planets is uncertain. A new hypothesis envisions rapid formation of several gaseous protoplanets in a marginally gravitationally-unstable protoplanetary disk, coagulation and settling of dust grains within the protoplanets to form rock and ice cores, followed by loss of the outer disk gas and the gaseous envelopes of the protoplanets through photoevaporation driven by nearby OB stars. We demonstrate here that the first part of this new scenario for ice giant planet formation is feasible, in a disk with a gas density similar to that believed to be necessary to form the giant planets. A three dimensional gravitational hydrodynamics code, including a full treatment of thermodynamics and radiative transfer in the diffusion approximation, is used to show that a disk is likely to form two or more gravitationally-bound clumps, with masses on the order of 2 Jupiter masses, between 20 AU and 30 AU from a solar-mass star. Such protoplanets could be massive enough to explain the production of Uranus and Neptune, following photoevaporation of most of their gaseous envelopes. This scenario implies that planetary systems similar to our own could form even in seemingly hostile regions of high mass star formation.

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

## Far UV spectroscopy of the circumstellar environment of the Herbig Be stars HD 259431 and HD 250550

J.-C. Bouret<sup>1</sup>, C. Martin<sup>2</sup>, M. Deleuil<sup>3</sup>, T. Simon<sup>4</sup> and C. Catala<sup>5</sup>

<sup>1</sup> Laboratoire d'Astrophysique de Marseille, Traverse du Siphon - BP 8, 13376 Marseille Cedex 12, France

<sup>2</sup> Laboratoire d'Astrophysique de Marseille, Traverse du Siphon - BP 8, 13376 Marseille Cedex 12, France

<sup>3</sup> Laboratoire d'Astrophysique de Marseille, Traverse du Siphon - BP 8, 13376 Marseille Cedex 12, France

<sup>4</sup> Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA

<sup>5</sup> Observatoire de Paris-Meudon, CNRS, Paris, France

E-mail contact: Jean-Claude.Bouret@oamp.fr

We present an analysis of *FUSE* spectra of HD 259431 and HD 250550, two young Herbig Be stars. Numerous

absorption lines of  $H_2$  are seen in the spectrum of each star, revealing large amounts of this gas on the lines of sight. In addition, absorption lines from atomic species in different ionization and excitation states are also identified. We demonstrate that all these species probe the close circumstellar environment around the stars, with two or even three temperature components in HD 259431, as revealed by molecular gas analysis. Although favouring the flared disk scenario, our results do not rule out the possibility that we actually detect CS envelopes/halos around these stars.

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## Theoretical $H_2CO$ emission from protostellar envelopes

C.Ceccarelli<sup>1</sup>, S.Maret<sup>2</sup>, A.G.G.M.Tielens<sup>3</sup>, A.Castets<sup>4</sup>, E.Caux<sup>2</sup>

<sup>1</sup> Laboratoire d'Astrophysique, Observatoire de Grenoble - BP 53, F-38041 Grenoble cedex 09, France

<sup>2</sup> CESR CNRS-UPS, BP 4346, 31028 - Toulouse cedex 04, France

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

<sup>4</sup> Observatoire de Bordeaux, BP 89, 33270 Floirac, France

E-mail contact: [ceccarel@obs.ujf-grenoble.fr](mailto:ceccarel@obs.ujf-grenoble.fr)

We present theoretical predictions of the formaldehyde emission from the envelopes of low mass protostars. The model accounts for the density profile across the envelope, assuming the Shu (1977) solution for the collapse, as well as for the gas temperature profile. The gas temperature is derived from the thermal balance according to the model previously developed by Ceccarelli, Hollenbach & Tielens (1996). The formaldehyde abundance profile is approximated by a step function: in the outer envelope it is similar to that of molecular clouds, whereas in the inner envelope, where the dust temperature reaches the ice mantle evaporation temperature, it jumps to larger values. The results of the modeling for a  $30 L_\odot$  source are reported for a large range of values of the formaldehyde abundance, both in the inner and outer envelope. Additional results for sources with different luminosities can be found in the web site [www-laog.obs.ujf-grenoble.fr/~ceccarel/mepew/mepew.html](http://www-laog.obs.ujf-grenoble.fr/~ceccarel/mepew/mepew.html). They are meant to be directly used by the interested reader to estimate the two main parameters of the model: the inner and outer formaldehyde abundance. The model is applied to the observations of the well known low mass protostar IRAS16293-2422 to illustrate the practical use of the diagnostic tools. Furthermore, we discuss how the observation of the  $H_2^{12}CO$  and  $H_2^{13}CO$  lines can in principle be used to discriminate between infalling and outflowing gas. Finally, the same web site hosts simpler non-LTE LVG predictions for a large range of densities, temperatures and column densities of several molecules. Again the goal of the web site is to provide users with easy to use theoretical predictions for a first assessment of expected and/or observed signals.

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<http://www-laog.obs.ujf-grenoble.fr/~ceccarel/>

## An Unusual Eclipse of a Pre-Main Sequence Star in IC 348

R.E. Cohen<sup>1</sup>, W. Herbst<sup>1</sup> and E. C. Williams<sup>1</sup>

<sup>1</sup> Astronomy Department, Wesleyan University, Middletown, CT 06459, USA

E-mail contact: [wherbst@wesleyan.edu](mailto:wherbst@wesleyan.edu)

A solar-like pre-main sequence star (TJ 108 = H 187 = LRL 35 = HMW 15) in the extremely young cluster IC 348 has been found, which apparently experienced an eclipse lasting  $\sim 3.5$  years, much longer than has ever been detected for any normal eclipsing binary. The light curve is flat-bottomed and rather symmetric, with a depth of 0.66 mag in Cousins I. During eclipse, the system reddened by  $\sim 0.17$  mag in R-I. We argue that the eclipsing body is not a star because of the small probability of detecting an eclipse in what would be a very widely separated binary. Instead, it appears that the eclipse was caused by a circumstellar or circumbinary cloud or disk feature which occulted the star, or one of its components, if it is a binary system. We emphasize the importance of more detailed study of this object, which appears to be a new member of a small class of pre-main sequence stars whose variability can be firmly linked to occultation by circumstellar (or circumbinary) matter.

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# Thermo-Hydrodynamics of Circumstellar Disks with High-mass Planets

Gennaro D’Angelo<sup>1</sup>, Thomas Henning<sup>2</sup>, and Willy Kley<sup>3</sup>B

<sup>1</sup> School of Physics, University of Exeter, United Kingdom

<sup>2</sup> Max Planck Institute for Astronomy, Heidelberg, Germany

<sup>3</sup> Computational Physics, University of Tuebingen, Tuebingen, Germany

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

With a series of numerical simulations, we analyze the thermo-hydrodynamical evolution of circumstellar disks containing Jupiter-size protoplanets. In the framework of the two-dimensional approximation, we consider an energy equation that includes viscous heating and radiative effects in a simplified, yet consistent form. Multiple nested grids are used in order to study both global and local features around the planet. By means of different viscosity prescriptions, we investigate various temperature regimes. A planetary mass range from 0.1 to 1  $M_J$  is examined. Computations show that gap formation is a general property which affects density, pressure, temperature, optical thickness, and radiated flux distributions. However, it remains a prominent feature only when the kinematic viscosity is on the order of  $10^{15} \text{ cm}^2 \text{ s}^{-1}$  or lower, though it becomes rather shallow for 0.1  $M_J$  perturbers. Around accreting planets, a circumplanetary disk forms that has a surface density profile decaying exponentially with the distance and whose mass is 5–6 orders of magnitudes smaller than Jupiter’s mass. Circumplanetary disk temperature profiles decline roughly as the inverse of the distance from the planet, matching the values measured in the gap toward the border of the Roche lobe. Temperatures range from some 10 to  $\sim 1000 \text{ K}$ . Moreover, circumplanetary disks are generally opaque, with optical thickness larger than 1 and aspect ratios around a few tenths. Non-accreting protoplanets provide quite different scenarios, with a clockwise, i.e., reversed flow rotation around low-mass bodies. Planetary accretion and migration rates depend on the viscosity regime, with discrepancies within an order of magnitude. Coorbital torques increase as viscosity increases. For high viscosities, Type I migration may extend to larger planetary masses. Estimates of growth and migration time scales inferred by these models are on the same orders of magnitude as those previously obtained with locally isothermal simulations, both in two and three dimensions.

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The paper is available as an ApJ Preprint at

<http://www.journals.uchicago.edu/ApJ/journal/preprints/ApJ58258.preprint.pdf>

# A Spectroscopic Technique for Measuring Stellar Properties of Pre–Main Sequence Stars

G.W. Doppmann<sup>1,2</sup> and D.T. Jaffe<sup>2</sup>

<sup>1</sup> NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035-1000, USA

<sup>2</sup> Department of Astronomy, 1 University Station C1400, Austin, TX 78712-1083, USA

E-mail contact: gdoppmann@mail.arc.nasa.gov

We describe a technique for deriving effective temperatures, surface gravities, rotation velocities, and radial velocities from high resolution near-IR spectra. The technique matches the observed near-IR spectra to spectra synthesized from model atmospheres. Our analysis is geared toward characterizing heavily reddened pre-main sequence stars but the technique also has potential applications in characterizing main sequence and post-main sequence stars when these lie behind thick clouds of interstellar dust. For the pre-main sequence stars, we use the same matching process to measure the amount of excess near-IR emission (which may arise in the protostellar disks) in addition to the other stellar parameters. The information derived from high resolution spectra comes from line shapes and the relative line strengths of closely spaced lines. The values for the stellar parameters we derive are therefore independent of those derived from low resolution spectroscopy and photometry. The new method offers the promise of improved accuracy in placing young stellar objects on evolutionary model tracks. Tests with an artificial noisy spectrum with typical stellar parameters, and signal-to-noise of 50 indicates a  $1\sigma$  error of 100 K in  $T_{\text{eff}}$ , 2 km  $\text{s}^{-1}$  in  $v \sin i$ , and 0.13 in continuum veiling for an input veiling of 1. If the line flux ratio between the sum of the Na, Sc, and Si lines at 2.2  $\mu\text{m}$  and the (2–0)  $^{12}\text{CO}$  bandhead at 2.3  $\mu\text{m}$  is known to an accuracy of 10%, the errors in our best fit value for  $\log g$  will be  $\Delta \log g = 0.1\text{--}0.2$ . We discuss the possible systematic effects on our determination of the stellar parameters and evaluate the accuracy of the results derivable from high resolution spectra. In the context of this evaluation, we explore quantitatively the degeneracy between temperature and gravity that has bedeviled efforts to type young stellar objects using low resolution spectra. The analysis of high resolution near-IR spectra of MK standards shows

that the technique gives very accurate values for the effective temperature. The biggest uncertainty in comparing our results with optical spectral typing of MK standards is in the spectral type to effective temperature conversion for the standards themselves. Even including this uncertainty, the  $1\sigma$  difference between the optical and IR temperatures for 3000–5800 K dwarfs is only 140 K. In a companion paper (Doppmann, Jaffe, and White 2003), we present an analysis of heavily extinguished young stellar objects in the  $\rho$  Ophiuchi molecular cloud.

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## Stellar Properties of Pre–Main Sequence Stars from High Resolution Near–IR Spectra

G.W. Doppmann<sup>1,2</sup>, D.T. Jaffe<sup>2</sup>, and R.J. White<sup>2,3</sup>

<sup>1</sup> NASA Ames Research Center, MS 245-6, Moffett Field, CA 94035-1000, USA

<sup>3</sup> Department of Astronomy, 1 University Station C1400, Austin, TX 78712-1083, USA

<sup>4</sup> California Institute of Technology, Department of Astronomy, MS 105-24, Pasadena, CA 91125, USA

E-mail contact: [gdoppmann@mail.arc.nasa.gov](mailto:gdoppmann@mail.arc.nasa.gov)

We present high resolution ( $R=50,000$ ) spectra at  $2.2\ \mu\text{m}$  of 16 young stars in the  $\rho$  Ophiuchi dark cloud. Photospheric features are detected in the spectra of 11 of these sources, all Class II young stellar objects. The 5 featureless spectra consist of 2 Class I, 2 Class I.5, & 1 Class II. One star, GSS 29, is identified as a spectroscopic binary based on radial velocity variations. The radial velocities for the remaining sample are consistent with  $^{12}\text{CO}$  and  $\text{H}_2\text{CO}$  gas velocities and further confirm the membership of the sources in the  $\rho$  Ophiuchi cluster. For the 10 spectroscopically single Class II sources, we measure effective temperatures, continuum veiling, and  $v \sin i$  rotation from the shapes and strengths of atomic photospheric lines by comparing to spectral synthesis models at  $2.2\ \mu\text{m}$ . We measure surface gravities in 2 stars from the integrated line flux ratio of the  $^{12}\text{CO}$  line region at  $2.3\ \mu\text{m}$  and the Na I line region at  $2.2\ \mu\text{m}$ . Although the majority (8/10) of the Class II stars have similar effective temperatures ( $3530\ \text{K} \pm 100\ \text{K}$ ), they exhibit a large spread in bolometric luminosities (factor  $\sim 8$ ), as derived from near-IR photometry. In the two stars where we have surface gravity measurements from spectroscopy, the photometrically derived luminosities are systematically higher than the spectroscopic luminosities. The spread in the photometrically derived luminosities in our other sources suggests either a large spread in stellar ages, or non-photospheric emission in the J-band since anomalous and significant veiling at J has been observed in other T Tauri stars. Our spectroscopic luminosities result in older ages on the Hertzsprung–Russell diagram than is suggested by photometry at J or K. Most of our sources show a larger amount of continuum excess ( $F_{\text{Kex}}$ ) than stellar flux at  $2.2\ \mu\text{m}$  ( $F_{\text{K*}}$ ), substantially higher in many cases ( $r_{\text{K}} \equiv F_{\text{Kex}}/F_{\text{K*}} = 0.3\text{--}4.5$ ). The derived veiling values at K ( $r_{\text{K}}$ ) appear correlated with mid-IR disk luminosity, and with Brackett  $\gamma$  equivalent width, corrected for veiling. The derived  $v \sin i$  rotation is substantial ( $12\text{--}39\ \text{km s}^{-1}$ ), but systematically less than the rotation measured in Class I.5 (flat) and Class I sources from other studies in Ophiuchus. In four stars (Class I and I.5 sources), the absence of any photospheric lines is likely due to large continuum excess and/or rapid rotation if the stars have late-type photospheres.

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## Distribution of Circumstellar Disk Masses in the Young Cluster NGC 2024

J. A. Eisner<sup>1</sup> and John M. Carpenter<sup>1</sup>

<sup>1</sup> California Institute of Technology, Department of Astronomy MC 105-24, Pasadena, CA 91125, USA

E-mail contact: [jae@astro.caltech.edu](mailto:jae@astro.caltech.edu)

We determine the distribution of circumstellar disk masses in the young ( $\sim 0.3\ \text{Myr}$ ) cluster NGC 2024 by imaging a  $2'.5 \times 2'.5$  region in  $\lambda 3\text{mm}$  continuum emission to an RMS noise level of  $\sim 0.75\ \text{mJy beam}^{-1}$  with the Owens Valley Millimeter Array. The mosaic encompasses 147 K-band sources as well as the molecular ridge seen previously in dust continuum emission. We detect 10 point-like sources in  $\lambda 3\text{mm}$  continuum emission above the level of  $5\sigma$  within the unit gain region of the mosaic. One of these sources corresponds to the near-IR source IRS 2, an early B-type star. Two other sources are tentatively associated with low-mass near-IR cluster members, and the remaining 7 sources have no K-band counterparts. Assuming the millimeter continuum point sources represent emission from circumstellar

disks and/or envelopes, then  $\sim 6\%$  of the total population (infrared and millimeter sources) in the NGC 2024 mosaic has a circumstellar mass in excess of  $\sim 0.06 M_{\odot}$ . We obtain further constraints on the average circumstellar disk mass by considering the mean millimeter continuum flux observed toward a sample of 140 K-band sources that likely have stellar masses  $< 1 - 2 M_{\odot}$ . While none of these sources are detected individually above the  $3\sigma$  limit of  $\sim 0.035 M_{\odot}$ , the ensemble of sources are detected in the mean at the  $5\sigma$  level with a mean disk mass of  $\sim 0.005 M_{\odot}$ . Compared to the older ( $\sim 2$  Myr) cluster IC 348, NGC 2024 contains a higher frequency of massive disks/envelopes and has a higher mean disk mass by a factor of  $2.5 \pm 1.3$  among K-band sources, suggesting that the mean circumstellar mass is decreasing with cluster age. We also compare the results for the NGC 2024 and IC 348 clusters to those for the lower-density Taurus star forming region. Finally, we compare our detection limits with the minimum mass estimate for the proto-solar nebula, and discuss possible implications for planet formation.

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## The $\epsilon$ Chamaeleontis young stellar group and the characterization of sparse stellar clusters

Eric D. Feigelson<sup>1,2</sup>, Warrick A. Lawson<sup>2</sup> and Gordon P. Garmire<sup>1</sup>

<sup>1</sup> Dept. of Astronomy & Astrophysics, Penn State University

<sup>2</sup> School Physics, Environmental & Mathematical Sciences, Australian Defence Force Academy

E-mail contact: [edf@astro.psu.edu](mailto:edf@astro.psu.edu)

We present the outcomes of a *Chandra X-ray Observatory* snapshot study of five nearby Herbig Ae/Be (HAeBe) stars which are kinematically linked with the Oph-Sco-Cen Association (OSCA). Optical photometric and spectroscopic followup was conducted for the HD 104237 field. The principal result is the discovery of a compact group of pre-main sequence (PMS) stars associated with HD 104237 and its codistant, comoving B9 neighbor  $\epsilon$  Chamaeleontis AB. We name the group after the most massive member. The group has five confirmed stellar systems ranging from spectral type B9–M5, including a remarkably high degree of multiplicity for HD 104237 itself. The HD 104237 system is at least a quintet with four low mass PMS companions in nonhierarchical orbits within a projected separation of 1500 AU of the HAeBe primary. Two of the low-mass members of the group are actively accreting classical T Tauri stars. The *Chandra* observations also increase the census of companions for two of the other four HAeBe stars, HD 141569 and HD 150193, and identify several additional new members of the OSCA.

We discuss this work in light of several theoretical issues: the origin of X-rays from HAeBe stars; the uneventful dynamical history of the high-multiplicity HD 104237 system; and the origin of the  $\epsilon$  Cha group and other OSCA outlying groups in the context of turbulent giant molecular clouds. Together with the similar  $\eta$  Cha cluster, we paint a portrait of sparse stellar clusters dominated by intermediate-mass stars 5 – 10 Myr after their formation.

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Available at [astro-ph/0309059](http://astro-ph/0309059) and, with higher quality figures, at [ftp.astro.psu.edu/pub/edf/epsCha.ps.gz](http://ftp.astro.psu.edu/pub/edf/epsCha.ps.gz) (2.4 MBy).

## Chandra Observations of a Young Embedded Magnetic B Star in the $\rho$ Ophiuchus Cloud

Kenji Hamaguchi,<sup>1,2</sup> Michael F. Corcoran,<sup>1,3</sup> and Kensuke Imanishi<sup>4</sup>

<sup>1</sup> Laboratory for High Energy Astrophysics, Goddard Space Flight Center, Greenbelt, MD 20771, USA

<sup>2</sup> National Research Council, 500 Fifth Street, NW, Washington, DC 20001, USA

<sup>3</sup> Universities Space Research Association, 7501 Forbes Blvd, Ste 206, Seabrook, MD 20706, USA

<sup>4</sup> Department of Physics, Faculty of Science, Kyoto University, Kitashirakawa-oiwakecho, Sakyo-ku, Kyoto 606-8502, Japan

E-mail contact: [kenji@milkyway.gsfc.nasa.gov](mailto:kenji@milkyway.gsfc.nasa.gov)

This paper reports on an analysis of two *Chandra X-ray* observations of the young magnetic B star  $\rho$  Ophiuchus S1. X-ray emission from the star was detected in both observations. The average flux was almost the same in both, but during each observation the flux showed significant time variations by a factor of two on timescales of 20–40 ks. Each spectrum could be fit by either an absorbed power-law model with a photon index of  $\sim 3$  or a thin-thermal plasma

model with a temperature of  $\sim 2$  keV and an extremely low metal abundance ( $\leq 0.1$  solar). The spectrum of the first observation has a weak-line feature at about 6.8 keV, which might correspond to highly ionized iron  $K\alpha$ . In contrast, the spectrum of the second observation apparently shows a weak edge absorption component at  $E \sim 4$  keV. The continuum emission and  $\log(L_X/L_{\text{bol}}) \sim -6$  are similar to those of young intermediate-mass stars (Herbig Ae/Be stars), although the presence of a strong magnetic field (inferred from the detection of non-thermal radio emission) has drawn an analogy between  $\rho$  Ophiuchus S1 and magnetic chemically peculiar (MCP) stars. If the X-ray emission is thermal, the small abundances that we derived might be related to the inverse first-ionization potential (FIP) effect, though there is no significant trend as a function of FIP from our model fits. If the emission is non-thermal, it might be produced by high-energy electrons in the magnetosphere.

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## The Formaldehyde Masers in NGC 7538 and G29.96-0.02: VLBA, MERLIN, and VLA Observations

Ian M. Hoffman<sup>1</sup>, W. M. Goss<sup>1</sup> and Patrick Palmer<sup>2</sup>

<sup>1</sup> National Radio Astronomy Observatory, P. O. Box O, Socorro, NM, USA 878 01

<sup>2</sup> Department of Astronomy and Astrophysics, 5640 S. Ellis Avenue, Chicago, IL, USA 60637

E-mail contact: [ihoffman@nrao.edu](mailto:ihoffman@nrao.edu)

The 6 cm formaldehyde ( $\text{H}_2\text{CO}$ ) maser sources in the compact HII regions NGC 7538-IRS1 and G29.96-0.02 have been imaged at high resolution ( $\theta_{\text{beam}} < 50$  mas). Using the VLBA and MERLIN, we find the angular sizes of the NGC 7538 masers to be  $\sim 10$  mas (30 AU) corresponding to brightness temperatures  $\sim 10^8$  K. The angular sizes of the G29.96-0.02 masers are  $\sim 20$  mas (130 AU) corresponding to brightness temperatures  $\sim 10^7$  K. Using the VLA, we detect 2 cm formaldehyde absorption from the maser regions. We detect no emission in the 2 cm line, indicating the lack of a 2 cm maser and placing limits on the 6 cm excitation process. We find that both NGC 7538 maser components show an increase in intensity on 5-10 year timescales while the G29.96-0.02 masers show no variability over 2 years. A search for polarization provides  $3\text{-}\sigma$  upper limits of 1% circularly polarized and 10% linearly polarized emission in NGC 7538 and of 15% circularly polarized emission in G29.96-0.02. A pronounced velocity gradient of  $28 \text{ km s}^{-1} \text{ arcsecond}^{-1}$  ( $1900 \text{ km s}^{-1} \text{ pc}^{-1}$ ) is detected in the NGC 7538 maser gas.

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## The spectral investigation of two Herbig-Haro objects - HH84 and HH85

E.R. Hovhannessian<sup>1</sup>, T.Yu. Magakian<sup>1</sup> and T.A. Movsessian<sup>1</sup>

<sup>1</sup> Byurakan Astrophysical Observatory, 378433, Aragatsotn prov., Armenia

E-mail contact: [helen@bao.sci.am](mailto:helen@bao.sci.am); [tigmag@sci.am](mailto:tigmag@sci.am)

The spectral investigations of two Herbig-Haro objects - HH84 and HH85 are presented. For the HH84 A, B, C, E knots and for HH85 A, B1, B2 knots the isocontours of [SII] emission lines, radial velocities, relative intensities of lines and electron densities are given. The comparison to results of other authors is performed. Significant variations of the radial velocities and line widths were found in the knots of HH84. This object indeed can represent the bow shock, which terminates a collimated outflow, but it is still unknown if this outflow is connected with HH83. HH85 definitely is a part of the HH34 giant outflow.

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## Kinematics of Ultracompact HII Regions Revealed: High Spatial and Spectral Resolution Mapping of the $12.8 \mu\text{m}$ [Ne II] Line in Monoceros R2

D.T. Jaffe<sup>1,2</sup>, Q.Zhu<sup>1</sup>, J.H. Lacy<sup>1</sup> and M. Richter<sup>1,3</sup>

<sup>1</sup> Department of Astronomy, University of Texas at Austin

<sup>2</sup> Guest Scientist, Max-Planck-Institut für extraterrestrische Physik

<sup>3</sup> Department of Physics, University of California, Davis

E-mail contact: dtj@astro.as.utexas.edu

We present the first results of a study of the kinematics and morphology of ultracompact H II regions using a new observational technique. We used very high spatial and spectral resolution observations ( $\theta_{Beam}=1.5$  arcsec,  $\Delta V=3.4$  km s<sup>-1</sup>) of the [Ne II] line at 12.8  $\mu$ m to study the ionized gas in Monoceros R2. The [Ne II] emission shows an H II region with highest emission measure in a  $\sim 24$  arcsec diameter shell, surrounded on all sides by neutral material. [Ne II] line widths are as narrow as 8 km s<sup>-1</sup> at some positions. In places where the lines are complex and broader the additional width is most likely due to overlap of narrower features along the line of sight. The narrow features themselves, however, are broader than the purely thermal width. The global kinematics suggest that the 24 arcsec shell is expanding at  $\approx 10$  km s<sup>-1</sup>. This interpretation leads to a dynamical age for the H II region of  $< 10^4$  years. However, the spectral profiles toward the brightest part of the nebula (on the southeast side of the shell) are not consistent with a simple expansion picture. Both the 24 arcsec shell and the bright southeast ridge can be part of a common kinematic pattern in which material flows from the bottom to the rim of a bowl-like feature. High-resolution observations of mid-IR fine structure transitions offer great promise as a probe of the kinematics and morphology of ionized regions around very young massive stars. Once appropriate theoretical modelling and observations of a larger sample of UCHII regions are in place, it should be possible to determine the physics behind the observed systematic motions in sources like Mon R2.

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## Grain Growth in the Dark Cloud L1251

Ryo Kandori<sup>1</sup>, Kazuhito Dobashi<sup>2</sup>, Hayato Uehara<sup>2</sup>, Fumio Sato<sup>2</sup>, and Kenshi Yanagisawa<sup>3</sup>

<sup>1</sup> Department of Astronomical Science, Graduate University for Advanced Studies (Sokendai), Osawa, Mitaka, Tokyo 181-8588, Japan

<sup>2</sup> Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Koganei, Tokyo 184-8501, Japan

<sup>3</sup> Okayama Astrophysical Observatory, National Astronomical Observatory of Japan, Kamogata, Okayama 719-0232, Japan

E-mail contact: kandori@alma.mtk.nao.ac.jp

We have performed optical imaging observations of the dark cloud L1251 at multiple wavelengths,  $B$ ,  $V$ ,  $R$ , and  $I$ , using the 105 cm Schmidt telescope at the Kiso Observatory, Japan. The cloud has a cometary shape with a dense “head” showing star formation activity and a relatively diffuse “tail” without any signs of star formation. We derived extinction maps of  $A_B$  and  $A_V$  with a star count method, and also revealed the color excess ( $E_{B-V}$ ,  $E_{V-R}$ , and  $E_{V-I}$ ) distributions. On the basis of the color excess measurements we derived the distribution of the ratio of total to selective extinction  $R_V$  over the cloud using an empirical relation between  $R_V$  and  $A_\lambda/A_V$  reported by Cardelli et al. In the tail of the cloud,  $R_V$  has a uniform value of  $\sim 3.2$ , close to that often found in the diffuse interstellar medium ( $\sim 3.1$ ), while higher values of  $R_V=4-6$  are found in the dense head. Since  $R_V$  is closely related to the size of dust grains, the high  $R_V$ -values are most likely to represent the growth of dust grains in the dense star-forming head of the cloud.

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## Magnetorotationally-Driven Galactic Turbulence and the Formation of Giant Molecular Clouds

Woong-Tae Kim<sup>1,2</sup>, Eve C. Ostriker<sup>2,1,3</sup>, and James M. Stone<sup>2,4</sup>

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

<sup>2</sup> Department of Astronomy, University of Maryland College Park, MD 20742, USA

<sup>3</sup> Radcliffe Institute for Advanced Study, Harvard University, Cambridge, MA 02138, USA

<sup>4</sup> DAMTP, University of Cambridge, Wilberforce Road, Cambridge, England CB3 9EW

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

Giant molecular clouds (GMCs), where most stars form, may originate from self-gravitating instabilities in the interstellar medium. Using local three-dimensional magnetohydrodynamic simulations, we investigate ways in which galactic turbulence associated with the magnetorotational instability (MRI) may influence the formation and properties of these massive, self-gravitating clouds. Our disk models are vertically stratified with both gaseous and stellar gravity, and subject to uniform shear corresponding to a flat rotation curve. Initial magnetic fields are assumed to be weak and purely vertical. For simplicity, we adopt an isothermal equation of state with sound speed  $c_s = 7 \text{ km}^{-1}$ . We find that MRI-driven turbulence develops rapidly, with the saturated-state Shakura & Sunyaev parameter  $\alpha \sim (0.15 - 0.3)$  dominated by Maxwell stresses. Many of the dimensionless characteristics of the turbulence (e.g. the ratio of the Maxwell to Reynolds stresses) are similar to results from previous MRI studies of accretion disks, hence insensitive to the degree of vertical disk compression, shear rate, and the presence of self-gravity – although self-gravity enhances fluctuation amplitudes slightly. The density-weighted velocity dispersions in non- or weakly self-gravitating disks are  $\sigma_x \sim \sigma_y \sim (0.4 - 0.6)c_s$  and  $\sigma_z \sim (0.2 - 0.3)c_s$ , suggesting that MRI can contribute significantly to the observed level of galactic turbulence. The saturated-state magnetic field strength  $\bar{B} \sim 2\mu\text{G}$  is similar to typical galactic values. When self-gravity is strong enough, MRI-driven high-amplitude density perturbations are swing-amplified to form Jeans-mass ( $\sim 10^7 M_\odot$ ) bound clouds. Compared to previous unmagnetized or strongly-magnetized disk models, the threshold for nonlinear instability in the present models occurs for surface densities at least 50% lower, corresponding to the Toomre parameter  $Q_{\text{th}} \sim 1.6$ . We present evidence that self-gravitating clouds like GMCs formed under conditions similar to our models can lose much of their original spin angular momenta by magnetic braking, preferentially via fields threading near-perpendicularly to their spin axes. Finally, we discuss the present results within the larger theoretical and observational context, outlining directions for future study.

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Associated animations available at <http://cfa-www.astro.umd.edu/~wkim/MOVIES/GMRI>

## Vortices in the Co-orbital Region of an Embedded Protoplanet

Josef Koller<sup>1,2</sup>, Hui Li<sup>1</sup> and Douglas N.C. Lin<sup>3</sup>

<sup>1</sup> Los Alamos National Laboratory, X-1, MS P225, Los Alamos, NM 87545, USA

<sup>2</sup> Physics and Astronomy Dept., Rice University, MS 108, 6100 S. Main St, Houston TX 77005, USA

<sup>3</sup> UCO/Lick Observatory, University of California, Santa Cruz, CA 95064, USA

E-mail contact: [jkoller@lanl.gov](mailto:jkoller@lanl.gov)

We present global 2-D inviscid disk simulations with an embedded planet, emphasizing the non-linear dynamics in its co-orbital region. We find that the potential vorticity of the flow in this region is not conserved due to the presence of two spiral shocks produced by the planet. As the system evolves, the potential vorticity profile develops extrema (inflection points) which eventually render the flow unstable. Vortices are produced in association with the potential vorticity minima. Born in the separatrix region, these vortices experience close-encounters with the planet, consequently exerting strong torques on the planet. The existence of these vortices have important implications on understanding the migration rates of low mass planets.

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## Galactic-Field IMFs of Massive Stars

Pavel Kroupa and Carsten Weidner

Institut für Theoretische Physik und Astrophysik, Universität Kiel, D-24098 Kiel, Germany

E-mail contact: [pavel/weidner@astrophysik.uni-kiel.de](mailto:pavel/weidner@astrophysik.uni-kiel.de)

Over the past years observations of young and populous star clusters have shown that the stellar IMF appears to be an invariant featureless Salpeter power-law with an exponent  $\alpha = 2.35$  for stars more massive than a few  $M_\odot$ . A consensus has also emerged that most, if not all, stars form in stellar groups and star clusters, and that the mass function of young star clusters in the solar-neighborhood and in interacting galaxies can be described, over the mass range of a few  $10 M_\odot$  to  $10^7 M_\odot$ , as a power-law with an exponent  $\beta \approx 2$ . These two results imply that galactic-

field IMFs for early-type stars cannot, under any circumstances, be a Salpeter power-law, but that they must have a steeper exponent  $\alpha_{\text{field}} > 2.8$ . This has important consequences for the distribution of stellar remnants and for the chemo-dynamical and photometric evolution of galaxies.

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## A Massive Disk/Envelope in Shocked H<sub>2</sub> Emission around an UCHII Region

M. S. Nanda Kumar<sup>1</sup>, A. J. L. Fernandes<sup>1</sup>, T. R. Hunter<sup>2</sup>, C. J. Davis<sup>3</sup> & S. Kurtz<sup>4</sup>

<sup>1</sup> Centro de Astrofísica da Universidade do Porto, Rua das Estrelas, 7150-462 Porto, Portugal

<sup>2</sup> Harvard Smithsonian Center for Astrophysics, 60 Garden Street, MS-78 Cambridge, MA 02138, USA

<sup>3</sup> Joint Astronomy Center, 660 N. A'ohokū Place, University Park, Hilo, HI 96720, USA

<sup>4</sup> Instituto de Astronomia, UNAM-Morelia, Apartado postal 3-72, C.P.58090 Morelia, Michoacan, Mexico

E-mail contact: [nanda@astro.up.pt](mailto:nanda@astro.up.pt)

A multi-wavelength study of IRAS 07427-2400 in line and continuum emission was conducted to investigate the nature of a H<sub>2</sub> v=1-0 S(1) line emitting feature around this ultra-compact HII region. High resolution 3.6 cm continuum observations from the Very Large Array and 350  $\mu\text{m}$  continuum observations from the Caltech Submillimeter Observatory, combined with archival far-infrared data of IRAS 07427-2400 show a flux density distribution indicating a luminous ( $L=5.6\times 10^4 L_{\odot}$ ) point source associated with an ultra-compact HII region. A Grey body model fit to the flux density distribution yields a dust emissivity index ( $\beta\sim 0.66$ ) indicative of a circumstellar disk/envelope. Our C<sup>18</sup>O map shows a dense core centered on the continuum source, with the major axis roughly aligned with the H<sub>2</sub> feature. Position-velocity diagram of the C<sup>18</sup>O core obtained along the major axis show rotation with a velocity gradient of  $\sim 0.1 \text{ km s}^{-1} \text{ arcsec}^{-1}$ . New CO J=3-2 maps of the region are presented which reveal a massive molecular outflow from the IRAS source. We argue that the H<sub>2</sub> feature arises in a disk/envelope around IRAS 07427-2400 and not in an outflow. We present a near-infrared HK band spectrum of the H<sub>2</sub> features that shows several ro-vibrational emission lines of H<sub>2</sub> and [FeII]. Analysis of the line ratios indicates that the line emission is shock-excited and not due to fluorescence. We estimate an excitation temperature of  $\sim 1500 \text{ K}$  and an average extinction of  $A_v\sim 11 \text{ mag}$  to the H<sub>2</sub> feature. The line fluxes yield a mass accretion rate of  $\dot{M} \sim 2.6 \pm 0.9 \times 10^{-2} M_{\odot} \text{ yr}^{-1}$  and a lifetime of  $\sim 5000 \pm 1200 \text{ yr}$  resulting in a disk/envelope mass of  $140 \pm 50 M_{\odot}$ . The resulting Jeans Mass of  $2420 M_{\odot}$  indicates that the disk/envelope will not undergo fragmentation. IRAS 07427-2400 represents one of the most massive YSOs known to date forming via accretion mechanism.

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preprints: <http://www.astro.up.pt/investigacao/publicacoes/main.html>

<ftp://ftp.astro.up.pt/pub/preprints/146.ps.gz>

## High Angular Resolution Measurement of Ion and Neutral Spectra as a Probe of the Magnetic Field Structure in DR21(OH)

Shih-Ping Lai<sup>1,2</sup>, T. Velusamy<sup>1</sup> and W. D. Langer<sup>1</sup>

<sup>1</sup> Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

<sup>2</sup> Current address: Department of Astronomy, University of Maryland, College Park, MD 20742, USA

E-mail contact: [slai@astro.umd.edu](mailto:slai@astro.umd.edu)

It has been suggested that under average interstellar field strengths the cyclotron interaction between ions and magnetic fields is strong enough to narrow the linewidth and suppress the line wings in the ion spectra. We present evidence for the cyclotron interaction effect at arcsec scale on the velocity dispersions in the spectra of ion/neutral molecular species in DR21(OH) observed with the OVRO-MMA. Using a spatial resolution  $\sim 3$  times higher than previous CSO observations by Houde et al. (2002), we show that H<sup>13</sup>CO<sup>+</sup> and H<sup>13</sup>CN are coexistent at the scale of our observations (6"). In the eastern parts of the DR21(OH) core where the dynamics is simple, the ion linewidths are indeed narrower than the neutral linewidths with an average ion-to-neutral linewidth ratio of  $0.82 \pm 0.04$ . We use our results, along with the existing Zeeman and dust/CO polarization data on small scales, to derive the 3-D magnetic field structure. We obtain a field strength of  $0.44 \pm 0.12 \text{ mG}$  with inclination of  $36^\circ$  to the line of sight, directed toward the observer,

and a position angle of  $-75^\circ$  in the plane of the sky. With the full magnetic field strength derived here, we are able to conclude that the MM1 core of DR21(OH) is magnetically supercritical; although turbulence provides the dominant support.

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## UV circular polarisation in star formation regions: the origin of homochirality?

P.W.Lucas<sup>1</sup>, J.H.Hough<sup>1</sup>, Jeremy Bailey<sup>2</sup>, Antonio Chrysostomou<sup>1</sup>, T.M.Gledhill<sup>1</sup>, Alan McCall<sup>1</sup>

<sup>1</sup> Department of Physical Sciences, University of Hertfordshire, College Lane, Hatfield AL10 9AB, UK.

<sup>2</sup> Anglo-Australian Observatory, Post Office Box 296, Epping, New South Wales 121, Australia

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

Ultraviolet circularly polarised light has been suggested as the initial cause of the homochirality of organic molecules in terrestrial organisms, via enantiomeric selection of prebiotic molecules by asymmetric photolysis. We present a theoretical investigation of mechanisms by which ultraviolet circular polarisation may be produced in star formation regions. In the scenarios considered here, light scattering produces only a small percentage of net circular polarisation at any point in space, due to the forward throwing nature of the phase function in the ultraviolet. By contrast, dichroic extinction can produce a fairly high percentage of net circular polarisation ( $\sim 10\%$ ) and may therefore play a key role in producing an enantiomeric excess.

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## Phase-Referenced VLBA Observations of OH Masers at 4765 MHz

Patrick Palmer<sup>1</sup>, W. M. Goss<sup>2</sup> and K. E. Devine<sup>3</sup>

<sup>1</sup> Department of Astronomy and Astrophysics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA

<sup>2</sup> National Radio Astronomy Observatory, Socorro, NM 87801, USA

<sup>3</sup> Carleton College, Northfield, MN 55057, USA

E-mail contact: ppalmer@oskar.uchicago.edu

We report VLBA observations of maser emission from the rotationally excited  $^2\Pi_{1/2}, J = 1/2$  state of OH at 4765 MHz. We made phase-referenced observations of W3(OH) at both 4765 MHz and 1720 MHz and found emission in three fields within a  $\sim 2000$  AU diameter region and verified that in two of the three fields, 4765 MHz and 1720 MHz emission arise from the same position to within  $\sim 4$  mas ( $\sim 8$  AU). We imaged DR21EX without phase-referencing and detected six  $\sim 5$  AU diameter emission regions along an approximately N-S arc with linear extent  $\sim 500$  AU. In addition, we carried out phase-referenced observations of 4765 MHz emission from K3-50. We searched for the 4765 MHz line in W49 (without phase referencing) and W75N (phase-referenced to the strongest 4765 MHz maser feature in DR21EX); we were unable to detect these sources with the VLBA. For 2 1/2 years (including the dates of the VLBA observations), we carried out monitoring observations of 4765 MHz emission with the VLA. Constraints on models for maser emission at 1720 MHz and 4765 MHz are derived from the observations. These observations are then briefly compared with existing models.

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## XMM-Newton study of the Serpens star forming region

Thomas Preibisch

Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

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

We analyze a XMM-Newton X-ray observation of the Serpens dark cloud with a total MOS-equivalent exposure time of 57 ksec. We find 45 individual X-ray sources. None of the class 0 protostars, only one of the class I protostars,

and two of the flat-spectrum objects in the region are detected in X-rays. The optically invisible flat-spectrum source EC 95, a very young intermediate mass object, is the strongest X-ray source in the Serpens cloud. The analysis of its X-ray spectrum shows that the hydrogen column density towards EC 95 is considerably lower than expected from the extinction determined from near-IR spectroscopy and photometry. Possible reasons for this inconsistency are discussed.

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Preprints are available at <http://www.mpifr-bonn.mpg.de/staff/tpreibis/publications.html> (paper # 36)

## Continuum and CO/HCO<sup>+</sup> Emission from the Disk Around the T Tauri Star LkCa 15

Chunhua Qi<sup>1,2</sup>, Jacqueline E. Kessler<sup>3</sup>, David W. Koerner<sup>4</sup>, Anneila I. Sargent<sup>5</sup>, and Geoffrey A. Blake<sup>1,3</sup>

<sup>1</sup> Division of Geological & Planetary Sciences, California Institute of Technology 150–21, Pasadena, CA 91125, USA

<sup>2</sup> Harvard–Smithsonian Center for Astrophysics, 60 Garden Street, MS 42, Cambridge, MA 02138, USA

<sup>3</sup> Division of Chemistry & Chemical Engineering, California Institute of Technology, Pasadena, CA 91125, USA

<sup>4</sup> Department of Physics and Astronomy, Northern Arizona University, P.O. Box 6010, Flagstaff, Arizona 86011, USA

<sup>5</sup> Division of Physics, Mathematics & Astronomy, California Institute of Technology 103–33, Pasadena, CA 91125, USA

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

We present OVRO Millimeter Array  $\lambda = 3.4 - 1.2$  mm dust continuum and spectral line observations of the accretion disk encircling the T Tauri star LkCa 15. The 1.2 mm dust continuum emission is resolved, and gives a minimum diameter of 190 AU and an inclination angle of  $57 \pm 5^\circ$ . There is a noticeable, but at present poorly constrained, decrease in the continuum spectral slope with frequency that may result from the coupled processes of grain growth and dust settling. Imaging of the fairly intense emission from the lowest rotational transitions of CO, <sup>13</sup>CO and HCO<sup>+</sup> reveals a rotating disk substantially larger than that observed in the dust continuum. Emission extends to  $\sim 750$  AU and the characteristic radius of the disk is determined to be  $\sim 425$  AU (HWHM), based on model fits to the CO velocity field. The measured line ratios demonstrate that the emission from these species is optically thick, while that from C<sup>18</sup>O and H<sup>13</sup>CO<sup>+</sup> is optically thin, or nearly so. The disk mass derived from the CO isotopologues with “typical” dense cloud abundances is still nearly two orders of magnitude less than that inferred from the dust emission, the most probable explanation being extensive molecular depletion in the cold, dense disk midplane. Thus, while CO, HCO<sup>+</sup> and their isotopologues are excellent tracers of the disk velocity field, they are not reliable tracers of the disk mass.

N<sub>2</sub>H<sup>+</sup> 1→0 emission has also been detected which, along with HCO<sup>+</sup>, sets a lower limit to the fractional ionization of 10<sup>-8</sup> in the near-surface regions of protoplanetary disks. This first detection of N<sub>2</sub>H<sup>+</sup> in circumstellar disks has also made possible a determination of the N<sub>2</sub>/CO ratio ( $\sim 2$ ) that is at least an order of magnitude larger than those in the envelopes of young stellar objects and dense clouds. The large N<sub>2</sub>/CO ratio indicates that our observations probe disk layers in which CO is depleted but some N<sub>2</sub> remains in the gas phase. Such differential depletion can lead to large variations in the fractional ionization with height in the outer reaches of circumstellar disks, and may help to explain the relative nitrogen deficiency observed in comets.

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## A CS $J = 5 \rightarrow 4$ Mapping Survey Towards High-mass Star Forming Cores Associated with Water Masers

Yancy L. Shirley<sup>1</sup>, Neal J. Evans II<sup>2</sup>, Kaisa E. Young<sup>2</sup>, Claudia Knez<sup>2</sup>, and Daniel T. Jaffe<sup>2</sup>

<sup>1</sup> NRAO, P.O. Box 0, 1003 Lopezville Rd., Socorro, NM 87801, USA

<sup>2</sup> Department of Astronomy, The University of Texas at Austin, 1 University Station C1400, Austin, Texas 78712–1083, USA

E-mail contact: [yshirley@aoc.nrao.edu](mailto:yshirley@aoc.nrao.edu); Download paper from: <http://www.aoc.nrao.edu/~yshirley/papers.html>

We have mapped 63 regions forming high-mass stars in CS  $J = 5 \rightarrow 4$  using the CSO. The CS peak position was observed in C<sup>34</sup>S  $J = 5 \rightarrow 4$  towards 57 cores and in <sup>13</sup>CS  $J = 5 \rightarrow 4$  towards the 9 brightest cores. The sample is a subset of a sample originally selected toward water masers; the selection on maser sources should favor sources in an

early stage of evolution. The cores are located in the first and second galactic quadrants with an average distance of  $5.3 \pm 3.7$  kpc and were well detected with a median peak signal-to-noise in the integrated intensity of 40. The integrated intensity of CS  $J = 5 \rightarrow 4$  correlates very well with the dust continuum emission at  $350 \mu\text{m}$ . For 57 sufficiently isolated cores, a well-defined angular size (FWHM) was determined. The core radius ( $R_{CS}$ ), aspect ratio ( $(a/b)_{obs}$ ), virial mass ( $M_{vir}$ ), surface density ( $\Sigma$ ), and the luminosity in the CS  $J = 5 \rightarrow 4$  line ( $L(\text{CS}54)$ ) are calculated. The distributions of size, virial mass, surface density, and luminosity are all peaked with a few cores skewed towards much larger values than the mean. The median values,  $\mu_{1/2}$ , are as follows:  $\mu_{1/2}(R_{CS}) = 0.32$  pc,  $\mu_{1/2}(\text{AR } 6) = 1.20$ ,  $\mu_{1/2}(M_{vir}) = 920 M_{\odot}$ ,  $\mu_{1/2}(\Sigma) = 0.60 \text{ g cm}^{-2}$ ,  $\mu_{1/2}(L(\text{CS}54)) = 1.9 \times 10^{-2} L_{\odot}$ , and  $\mu_{1/2}(L_{bol}/M_{vir}) = 165 L_{\odot}/M_{\odot}$ . We find a weak correlation between  $\text{C}^{34}\text{S}$  linewidth and size, consistent with  $\Delta v \sim R^{0.3}$ . The linewidths are much higher than would be predicted by the usual relations between linewidth and size determined from regions of lower mass. These regions are very turbulent. The derived virial mass agrees within a factor of 2 to 3 with mass estimates from dust emission at  $350 \mu\text{m}$  after corrections for the density structure are accounted for. The resulting cumulative mass spectrum of cores above  $1000 M_{\odot}$  can be approximated by a power law with a slope of about  $-0.9$ , steeper than that of clouds measured with tracers of lower density gas and close to that for the total masses of stars in OB associations. The median turbulent pressures are comparable to those in UCH II regions, and the pressures at small radii are similar to those in hypercompact H II regions ( $P/k \sim 10^{10} \text{ K cm}^{-3}$ ). The filling factors for dense gas are substantial, and the median abundance of CS is about  $10^{-9}$ . The ratio of bolometric luminosity to virial mass is much higher than the value found for molecular clouds as a whole, and the correlation of luminosity with mass is tighter.

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## How do binary separations depend on cloud initial conditions?

Michael F. Sterzik<sup>1</sup>, Richard H. Durisen<sup>2</sup> and Hans Zinnecker<sup>3</sup>

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

<sup>2</sup> Department of Astronomy, SW319, Indiana University, Bloomington, Indiana 47405, U.S.A.

<sup>3</sup> Astrophysikalisches Institut Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany

E-mail contact: msterzik@eso.org

We explore the consequences of a star formation scenario in which the isothermal collapse of a rotating, star forming core is followed by prompt fragmentation into a cluster containing a small number ( $N \leq 10$ ) of protostars and/or substellar objects. The subsequent evolution of the cluster is assumed to be dominated by dynamical interactions among cluster members, and this establishes the final properties of the binary and multiple systems. The characteristic scale of the fragmenting core is determined by the cloud initial conditions (such as temperature, angular momentum, and mass), and we are able to relate the separation distributions of the final binary population to the properties of the star forming core. Because the fragmentation scale right after the isothermal collapse is typically a factor 3-10 too large, we conjecture that fragmentation into small clusters followed by dynamical evolution is required to account for the observed binary separation distributions. Differences in the environmental properties of the cores are expected to imprint differences on the characteristic dimensions of the binary systems they form. Recent observations of hierarchical systems, differences in binary characteristics among star forming regions, and systematic variations in binary properties with primary mass can be interpreted in the context of this scenario.

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<http://www.sc.eso.org/~msterzik/Fragment/sterzik.ps>

## Proper motion and X-ray selected search for new members of the young TW Hya association

K. Tachihara<sup>1,2</sup>, R. Neuhäuser<sup>1,2</sup>, S. Frink<sup>3,4,5</sup>, and E. Guenther<sup>6</sup>

<sup>1</sup> Astrophysikarisches Institut und Universitäts Sternwarte Jena, D-07745, Jena, Germany

<sup>2</sup> Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany

<sup>3</sup> University of California San Diego, La Jolla, CA 92093, USA

<sup>4</sup> Astronomisches Rechen-Institut Heidelberg, Germany

<sup>5</sup> Sterrewacht Leiden, 2300 RA Leiden, The Netherlands

<sup>6</sup> Thüringer Landessternwarte, Tautenburg, Germany

E-mail contact: [tatihara@astro.uni-jena.de](mailto:tatihara@astro.uni-jena.de)

We have searched for new members of the TW Hya association (TWA) among unidentified ROSAT X-ray sources by identifying them in proper motion catalogues and selecting those that would be consistent with kinematical membership to the TWA. Spectroscopic follow-up observations of 19 member candidates revealed the detection of moderate lithium absorption lines for the following three stars: GSC 7206 845, TYC 7216-55, and TYC 7247-12. The isochronal ages of the latter TYC stars are estimated to be  $\sim 20$  Myr while the other one has  $\sim 100$  Myr age based on a kinematic distance estimate that assumes TWA membership. However, the moderately Li-rich stars are not likely to be new pre-main sequence members of TWA partly because of the discrepant radial velocities. Infrared follow-up imaging in the H-band for the 3 stars shows companion candidates near two of them. While one system (TYC 7216-55) is probably a near-equal-magnitude stellar binary, our follow-up H-band spectrum of the faint companion candidate near GSC 7206 845 shows that it is instead a background K-type star rather than a companion.

Accepted by *Astronomische Nachrichten*

<http://www.astro.uni-jena.de/Users/tatihara/research.html>

## Sulphur chemistry in the envelopes of massive young stars

F.F.S. van der Tak<sup>1</sup>, A.M.S. Boonman<sup>2</sup>, R. Braakman<sup>2</sup>, E.F. van Dishoeck<sup>2</sup>

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

<sup>2</sup> Sterrewacht, Postbus 9513, 2300 RA Leiden, The Netherlands

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

The sulphur chemistry in nine regions in the earliest stages of high-mass star formation is studied through single-dish submillimeter spectroscopy. The line profiles indicate that 10–50% of the SO and SO<sub>2</sub> emission arises in high-velocity gas, either infalling or outflowing. For the low-velocity gas, excitation temperatures are 25 K for H<sub>2</sub>S, 50 K for SO, H<sub>2</sub>CS, NS and HCS<sup>+</sup>, and 100 K for OCS and SO<sub>2</sub>, indicating that most observed emission traces the outer parts ( $T < 100$  K) of the molecular envelopes, except high-excitation OCS and SO<sub>2</sub> lines. Abundances in the outer envelopes, calculated with a Monte Carlo program, using the physical structures of the sources derived from previous submillimeter continuum and CS line data, are  $\sim 10^{-8}$  for OCS,  $\sim 10^{-9}$  for H<sub>2</sub>S, H<sub>2</sub>CS, SO and SO<sub>2</sub>, and  $\sim 10^{-10}$  for HCS<sup>+</sup> and NS. In the inner envelopes ( $T > 100$  K) of six sources, the SO<sub>2</sub> abundance is enhanced by factors of  $\sim 100$ –1000. This region of hot, abundant SO<sub>2</sub> has been seen before in infrared absorption, and must be small,  $\lesssim 0.2$  arcsec (180 AU radius). The derived abundance profiles are consistent with models of envelope chemistry which invoke ice evaporation at  $T \sim 100$  K. Shock chemistry is unlikely to contribute. A major sulphur carrier in the ices is probably OCS, not H<sub>2</sub>S as most models assume. The source-to-source abundance variations of most molecules by factors of  $\sim 10$  do not correlate with previous systematic tracers of envelope heating. Without observations of H<sub>2</sub>S and SO lines probing warm ( $\gtrsim 100$  K) gas, sulphur-bearing molecules cannot be used as evolutionary tracers during star formation.

Accepted by *A&A*

[astro-ph/0309138](mailto:astro-ph/0309138)

## Investigation of 131 Herbig Ae/Be candidate stars

S.L.A. Vieira<sup>1</sup>, W.J.B. Corradi<sup>1</sup>, S.H.P. Alencar<sup>1</sup>, L.T.S. Mendes<sup>1</sup>, C.A.O. Torres<sup>2</sup>, G.R. Quast<sup>2</sup>, M.M. Guimarães<sup>1</sup> and L. da Silva<sup>3</sup>

<sup>1</sup> Departamento de Física – ICEx – UFMG, Caixa Postal 702, Belo Horizonte, 30161-970, Brasil

<sup>2</sup> Laboratório Nacional de Astrofísica – MCT, Rua Estados Unidos, 154, Itajubá, 37504-364, Brasil

<sup>3</sup> Observatório Nacional – MCT, Rua General José Cristino 77, São Cristóvão, Rio de Janeiro, 20921-400, Brasil

E-mail contact: [slvieira@fisica.ufmg.br](mailto:slvieira@fisica.ufmg.br)

We present a new catalog of 108 Herbig Ae/Be candidate stars identified in the Pico dos Dias Survey (PDS) together with 19 previously known candidates and four objects selected from the IRAS Faint Source Catalog. These 131 stars were observed with low and/or medium resolution spectroscopy and we complement these data with high resolution spectra of 39 stars.

The objects present a great variety of  $H\alpha$  line profiles and were separated according to them. Our study suggests that most of the time a Herbig Ae/Be star will present a double peak  $H\alpha$  line profile. Correlations among different physical parameters, such as spectral type and  $v \sin i$  with  $H\alpha$  line profiles were searched. We found no correlation among  $H\alpha$  line profiles and spectral type or  $v \sin i$  except for stars with P Cyg profile, where there is a correlation with  $v \sin i$ . We also use preliminary spectral energy distributions to seek for any influence of the circumstellar medium in the  $H\alpha$  line profiles. The presence of [O I] and [S II] forbidden lines is used together with the  $H\alpha$  line profiles and these preliminary spectral energy distributions to discuss the circumstellar environment of the Herbig Ae/Be candidates.

The distribution of the detected [O I] and [S II] forbidden lines among different spectral types points to a significantly higher occurrence of these lines among B stars, whereas the distribution among different  $H\alpha$  profile types indicates that forbidden lines are evenly distributed among each  $H\alpha$  line profile type.

Combining the distance estimates of the Herbig candidates with the knowledge of the interstellar medium distribution, we have found that 84 candidates can be associated with some of the more conspicuous SFRs, being in the right direction and at a compatible distance.

As a further means of checking the properties of the HAeBe candidates as well as their present evolutionary status the derived luminosities and effective temperatures, of the stars with possible association to the star forming regions and/or Hipparcos distances, were plotted together with a set of PMS evolutionary tracks on an HR diagram. A set of 14 stars were found out of their expected positions in the HR diagram.

Accepted by Astron. J.

## Disks and Halos in Pre-Main-Sequence Stars

Dejan Vinković<sup>1</sup>, Zeljko Ivezić<sup>2</sup>, Anatoly S. Miroshnichenko<sup>3</sup> and Moshe Elitzur<sup>1</sup>

<sup>1</sup> Department of Physics & Astronomy, University of Kentucky, Lexington, KY 40506, USA

<sup>2</sup> Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544, USA; H.N. Russel Fellow

<sup>3</sup> Department of Physics & Astronomy, University of Toledo, Toledo, OH 43606, USA

E-mail contact: dejan@pa.uky.edu

We study the IR emission from flared disks with and without additional optically thin halos. Flux calculations of a flared disk in vacuum can be considered a special case of the more general family of models in which the disk is imbedded in an optically thin halo. In the absence of such halo, flux measurements can never rule out its existence because the disk flaring surface defines a mathematically equivalent halo that produces the exact same flux at all IR wavelengths. When a flared disk with height  $H$  at its outer radius  $R$  is imbedded in a halo whose optical depth at visual wavelengths is  $\tau_{\text{halo}}$ , the system IR flux is dominated by the halo whenever  $\tau_{\text{halo}} > \frac{1}{4}H/R$ . Even when its optical depth is much smaller, the halo can still have a significant effect on the disk temperature profile. Imaging is the only way to rule out the existence of a potential halo, and we identify a decisive test that extracts a signature unique to flared disks from imaging observations.

Accepted by MNRAS

<http://arxiv.org/abs/astro-ph/0309037>

## Mapping the Circumstellar Environment of T Tauri with Fluorescent $H_2$ Emission

Frederick M. Walter<sup>1</sup>, Gregory Herczeg<sup>2</sup>, Alexander Brown<sup>3</sup>, David R. Ardila<sup>4</sup>, Gösta F. Gahm<sup>5</sup>, Christopher M. Johns-Krull<sup>6</sup>, Jack J. Lissauer<sup>7</sup>, Michal Simon<sup>1</sup>, and Jeff A. Valenti<sup>8</sup>

<sup>1</sup> Department of Physics and Astronomy, Stony Brook University, Stony Brook NY 11794-3800, USA

<sup>2</sup> JILA, University of Colorado, Boulder, CO 80309-0440

<sup>3</sup> Center for Astrophysics and Space Astronomy, University of Colorado, Boulder CO 80309-0389, USA

<sup>4</sup> Department of Physics & Astronomy, Johns Hopkins University, Baltimore MD, 21218, USA

<sup>5</sup> Stockholm University, AlbaNova, SE - 106 91 Stockholm, Sweden

<sup>6</sup> Department of Physics & Astronomy, Rice University, Houston TX 77005-1892, USA

<sup>7</sup> Space Science Division, 245-3, NASA/Ames Research Center, Moffett Field, CA 94035, USA

<sup>8</sup> Space Telescope Science Institute, Baltimore MD 21218, USA

E-mail contact: fwalter@astro.sunysb.edu

We have obtained three long-slit, far UV spectra of the pre-main sequence system T Tauri. These HST/STIS spectra show a strong and variable on-source spectrum composed of both fluoresced H<sub>2</sub> and stellar chromospheric lines. Extended H<sub>2</sub> emission is seen up to 10'' from the T Tau system. The on-source and extended H<sub>2</sub> are both pumped by H I Lyman  $\alpha$ . The on-source H<sub>2</sub> is pumped by the red wing of a broad, self-absorbed Ly  $\alpha$  line, while the progressions seen in the extended gas are pumped from near line center. This suggests that the extended H<sub>2</sub> is pumped locally, and not by the stellar Ly  $\alpha$  line. The H<sub>2</sub> to the north and west coincides with the evacuated cavity bounded by the optical reflection nebosity; to the south the extended H<sub>2</sub> coincides with the HH 255 outflow from the embedded infrared companion T Tau S. The spatial profile of the extended gas shows a prominent dip coincident with the position of T Tau S. This may be absorption by a disk associated with T Tau S. There is no evidence for absorption by a disk surrounding T Tau N large enough to obscure T Tau S.

Accepted by Astron. J.; scheduled to appear December 2003

Paper can be downloaded from <http://www.astro.sunysb.edu/fwalter/PUBS/TTAULS.ps>

## 2-D Radiative Transfer in Protostellar Envelopes: II. An Evolutionary Sequence

Barbara A. Whitney<sup>1</sup>, Kenneth Wood<sup>2</sup>, J. E. Bjorkman<sup>3</sup>, and Martin Cohen<sup>4</sup>

<sup>1</sup> Space Science Institute, 4750 Walnut Street, Boulder, CO 80301, USA

<sup>2</sup> School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, Fife, KY16 9AD, Scotland the Brave

<sup>3</sup> Ritter Observatory, MS 113, Department of Physics & Astronomy, University of Toledo, Toledo, OH 43606-3390, USA

<sup>4</sup> Radio Astronomy Laboratory, 601 Campbell Hall, University of California, Berkeley, CA 94720, USA

E-mail contact: bwhitney@colorado.edu

We present model spectral energy distributions, colors, polarization, and images for an evolutionary sequence of a low-mass protostar from the early collapse stage (Class 0) to the remnant disk stage (Class III). We find a substantial overlap in colors and SEDs between protostars embedded in envelopes (Class 0-I) and T Tauri disks (Class II), especially at mid-IR wavelengths. Edge-on Class I-II sources show double-peaked spectral energy distributions, with a short-wavelength hump due to scattered light and the long-wavelength hump due to thermal emission. These are the bluest sources in mid-IR color-color diagrams.

Since Class 0 and I sources are diffuse, the size of the aperture over which fluxes are integrated has a substantial effect on the computed colors, with larger aperture results showing significantly bluer colors. Viewed through large apertures, the Class 0 colors fall in the same regions of mid-IR color-color diagrams as Class I sources, and are even bluer than Class II-III sources in some colors. It is important to take this into account when comparing color-color diagrams of star formation regions at different distances, or different sets of observations of the same region. However the near-IR polarization of the Class 0 sources is much higher than the Class I-II sources, providing a means to separate these evolutionary states.

We varied the grain properties in the circumstellar envelope, allowing for larger grains in the disk midplane and smaller in the envelope. In comparing to models with the same grain properties throughout we find that the SED of the Class 0 source is sensitive to the grain properties of the envelope only—that is, grain growth in the disk in Class 0 sources cannot be detected from the SED. Grain growth in disks of Class I sources can be detected at wavelengths greater than 100  $\mu\text{m}$ .

Our image calculations predict that the diffuse emission from edge-on Class I and II sources should be detectable in the mid-IR with the Space Infrared Telescope Facility (SIRTF) in nearby star forming regions (out to several hundred parsecs).

Accepted by ApJ

Preprint is available at <http://www.astro.wisc.edu/glimpse/glimpsepubs.html>

# Resonant Trapping of Planetesimals by Planet Migration: Debris Disk Clumps and Vega's Similarity to the Solar System

M. C. Wyatt

UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK

E-mail contact: wyatt@roe.ac.uk

This paper describes a model which can explain the observed clumpy structures of debris disks. Clumps arise because after a planetary system forms its planets migrate due to angular momentum exchange with the remaining planetesimals. Outward migration of the outermost planet traps planetesimals outside its orbit into its resonances and resonant forces cause azimuthal structure in their distribution. The model is based on numerical simulations of planets of different masses,  $M_{pl}$ , migrating at different rates,  $\dot{a}_{pl}$ , through a dynamically cold ( $e < 0.01$ ) planetesimal disk initially at a semimajor axis  $a$ . Trapping probabilities and the resulting azimuthal structures are presented for a planet's 2:1, 5:3, 3:2, and 4:3 resonances. Seven possible dynamical structures are identified from migrations defined by  $\mu = M_{pl}/M_{\star}$  and  $\theta = \dot{a}_{pl}\sqrt{a/M_{\star}}$ . Application of this model to the 850 $\mu$ m image of Vega's disk shows its two clumps of unequal brightness can be explained by the migration of a Neptune-mass planet from 40 to 65AU over 56Myr; tight constraints are set on possible ranges of these parameters. The clumps are caused by planetesimals in the 3:2 and 2:1 resonances; the asymmetry arises because of the overabundance of planetesimals in the 2:1(u) over the 2:1(l) resonance. The similarity of this migration to that proposed for our own Neptune hints that Vega's planetary system may be much more akin to the solar system than previously thought. Predictions are made which would substantiate this model, such as the orbital motion of the clumpy pattern, the location of the planet, and the presence of lower level clumps.

Accepted by Astrophys. J. (scheduled for v. 598, December 1, 2003)

Preprint available at astro-ph/0308253

Also available from <http://www.roe.ac.uk/~wyatt/>

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/>.

## 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.

## *New Jobs*

### **Structure, Dynamics and Energy Balance of Molecular Clouds**

#### **PhD Student Position**

Stockholm Observatory, Stockholm University, Sweden

**Deadline: October 19, 2003**

The Star Formation/IR-group at the Stockholm Observatory (<http://www.astro.su.se/English/groups/infrared/ir.html>) invites applications from members of all nationalities for a 4-year research student position, funded by the Swedish National Space Board. The PhD thesis advisor will be René Liseau, Stockholm University.

The student's research is expected to be in the field of the physics of molecular clouds. Primarily based on data being collected with the Swedish-international submillimeter satellite ODIN ([http://www.snsb.se/eng\\_odin\\_intro.shtml](http://www.snsb.se/eng_odin_intro.shtml)), this research will be observational in nature, but will also include significant elements of theoretical modeling, in particular of the transport of radiation through optically (very) thick media. The results of this modeling are also expected to provide valuable input for the observational planning for the next generation FIR/submm space platforms, notably HIFI aboard the ESA Space Observatory *Herschel*.

Applications, including curriculum vitae, attested copies of the examination certificate(s) with grades, a copy of the under-graduate thesis, letters of reference/recommendation and other material relevant for the selection process should be marked Dnr 39/03 and sent to

Prof. René Liseau  
Stockholm Observatory  
AlbNova University Center  
Stockholm Center for Physics, Astronomy and Biotechnology  
Roslagstullsbacken 21  
SE-106 91 Stockholm  
Sweden  
Tel: +46-8-5537 8521  
Fax: +46-8-5537 8510  
e-mail: [rene@astro.su.se](mailto:rene@astro.su.se)

Closing date for the application is **October 19, 2003**. The exact date of commencement is negotiable but should not be later than 20 January 2004, i.e. the start of the spring semester.

Information regarding the graduate student program can be found at <http://www.astro.su.se/utbildning/graduate.html> and the director of graduate studies is Prof. Hans Olofsson, e-mail: [hans@astro.su.se](mailto:hans@astro.su.se), tel: +46-8-5537 8516.

# Postdoctoral Research Opportunities in Star and Planet Formation

## UNIVERSITY OF MICHIGAN

The University of Michigan is home to an active and growing research group in the areas of star and planet formation, brown dwarfs, extrasolar planets, and interferometry. Currently, our group includes four faculty members (Fred Adams, Ted Bergin, Ray Jayawardhana, John Monnier), three postdoctoral fellows (Karl Haisch, Diane Paulson, Ettore Pedretti), and several students. We have independent access to the two Magellan 6.5-meter telescopes in Chile and the MDM 2.4-meter and 1.3-meter telescopes on Kitt Peak, and also regularly use other major facilities including Keck, VLT, JCMT, IRAM, IOTA, and (soon) SIRTf. We would like to draw the attention of potential candidates with common research interests to the opportunity to apply for a postdoctoral fellowship through the Michigan Society of Fellows.

The Society invites applications for its prestigious postdoctoral fellowships from qualified candidates who are at the beginning of their academic careers, having received the Ph.D. between June 1, 2001 and September 1, 2004. Fellows are appointed as Assistant Professors in appropriate departments at the University of Michigan and as Postdoctoral Scholars in the Michigan Society of Fellows. They are expected to be in residence during the academic years of the fellowship, to teach for the equivalent of one academic year, to participate in the informal intellectual life of the Society, and to devote time to their independent research. The annual stipend will be \$44,558. **Application deadline is October 3.** Further information and application material can be obtained from <http://www.rackham.umich.edu/Faculty/society.html>

We would also welcome inquiries from those interested in bringing other independent fellowships (Hubble, SIRTf, NSF, Michelson, Chandra, Marie Curie, ESA) to Michigan. Please contact any of us at the email addresses listed below:

Fred Adams ([fca@umich.edu](mailto:fca@umich.edu))

Ted Bergin ([ebergin@umich.edu](mailto:ebergin@umich.edu))

Ray Jayawardhana ([rayjay@umich.edu](mailto:rayjay@umich.edu))

John Monnier ([monnier@umich.edu](mailto:monnier@umich.edu))

Department Web page: <http://www.astro.lsa.umich.edu>

## Astrobiology Postdoctoral Fellows - University of Hawaii

The Institute for Astronomy (IfA) invites applications for postdoctoral fellows with a strong interest in astrobiology to collaborate with the University of Hawaii's NASA Astrobiology Institute lead team members. The UH lead team will maintain an innovative multi-disciplinary research environment linking biological, microbiological, chemical, geological and astronomical sciences to investigate the origin, history, distribution and role of water as it relates to life in the universe. The core of this program will center around interactions with an interdisciplinary group of postdoctoral fellows. Areas of primary research collaboration will be (1) formation and measurement of astrobiologically important molecules such as sugars, aminoacids, carboxylic acids, carbon homologues, hopanes, steranes, and head to head isoprenoids, as well as interpretation of the redox environment as it pertains to life in water-rich extraterrestrial ice analog samples, (2) *star formation (IR spectroscopy of sources in and behind dark clouds; sub-mm interferometry of disks)*, (3) *studies of small solar system primitive bodies (including both IR spectra, and isotopic studies)*, (4) modeling the incorporation of water into pre-planetary grains; (5) mineralogy, petrology and isotope (D/H) chemistry of aqueously-altered carbonaceous chondrites; (6) incorporation of water into planetary bodies, its cycling between surface and interior and its subsequent loss to space; (7) aqueous alteration on Mars; (8) evolution and diversity of microorganisms, especially those living in extreme and unusual Earth environments; (9) experimental and field investigation of indigenous microbiota and energetics of potential metabolic pathways in ocean crust and mantle rocks as analogs for early Earth habitats; (10) the ecology and biogeochemistry of extreme aqueous environments on the Earth, including subglacial lakes, high-altitude lakes and fumaroles as analogs to habitats elsewhere in the solar system; (10) the development of astrobiological instruments; and (11) models of theoretical ocean-bearing extrasolar planets and their remote characterization (12) the development of collaborative multidisciplinary computing techniques.

Minimum qualifications include a Ph.D. and the expertise appropriate for the specific research focus selected by the applicant. This could include (but is not limited to):

- *Expertise in infrared astronomical spectroscopy and research experience in star formation, circumstellar disks, or small solar system bodies*
- *Experience with astronomical sub-millimeter spectroscopy & interferometry*
- Background in experimental physical chemistry (reaction dynamics, photo-chemistry, charged and neutral particle sources and high vacuum technology)
- Experience with solar nebula models
- Familiarity with basic analyses of seawater based fluids, microbial molecular genetic techniques, and thermodynamic modeling of fluid-rock solution systems;
- Strong research programming skills (Java/C++/other) with an interest in collaborative computing and/or artificial intelligence
- Experience with scanning and transmission electron microscopy, electron and ion microprobes; experience in geo/cosmochemistry or physicochemistry. - Experience in marine microbial ecology and biogeochemistry
- Molecular Biology and microbiology techniques
- Modeling of upper atmospheric chemistry and physics
- Analysis of remote sensing of terrestrial surface and atmosphere
- Experience in the design and construction of instrumentation

Additional desirable qualifications

- Education and public outreach is an integral part of the Astrobiology program and experience with or interest in E/PO will be considered positively in an application.

The successful candidates will have access to *unequaled astronomical observing facilities at the Mauna Kea and Haleakala observatories*, an Ultra-High Vacuum Surface scattering machine, a 5 spectrometer electron microprobe and scanning electron microscope, a prototype Cryobot, fully-equipped molecular biology and microbiology laboratories, the R/V Kilo Moana oceanographic research ship, and the University of Hawaii Undersea Research Laboratory. In addition, successful candidates will be in close proximity to a variety of unique aquatic habitats (open ocean, high-altitude lakes, fumaroles). Appointments will be up to 3 years assuming satisfactory progress. Fellows will receive a stipend of \$4,333 per mo, a relocation allowance and small research budget. Fellows may apply for an subsequent 2 year position as senior fellows.

Applicants are expected to propose a program of research in consultation with the lead team members. Please address application materials including a complete application form (<http://www.ifa.hawaii.edu/UHNAI/application.html>), which includes a CV, publication list, a research proposal describing connections to at least 2 lead team members (see

<http://www.ifa.hawaii.edu/UHNAI>) and a list of at least three professional references to Dr. Rolf Kudritzki, Director, Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822. Request that the letters of recommendation are sent directly to this same address. Further details may be obtained from Dr. Rolf Kudritzki at 808-956-8566 or email [kud@ifa.hawaii.edu](mailto:kud@ifa.hawaii.edu). Questions about the UH Astrobiology lead team's program may be directed to Dr. K. J. Meech. Applications will be reviewed beginning **December 15, 2003**, but the positions will remain open until filled. The University of Hawaii is an EEO/AA employer and encourages applications from women and minorities.

## **POSTDOCTORAL RESEARCH ASSOCIATE IN STAR FORMATION**

### **CARDIFF UNIVERSITY,**

Department of Physics & Astronomy,  
5 The Parade,  
PO Box 913,  
Cardiff, CF24 3YB, Wales,  
United Kingdom.

Tel: +4429-20874798

Fax: +4429-20874056

E-mail: [ant@astro.cf.ac.uk](mailto:ant@astro.cf.ac.uk)

Applications are invited for a post-doc position to work on star and planet formation with Professor Anthony Whitworth. The principal goal of the project is to simulate numerically the formation of low-mass stars, brown dwarves and giant planets via gravitational instability in protostellar discs, whilst treating properly the associated thermal and radiative processes. The appointee will also be encouraged to develop related projects, and to participate in other aspects of the ongoing star formation programme at Cardiff. Preference will be given to applicants with experience in astrophysical gas dynamics and/or radiation transport.

The Cardiff Star Formation Group currently comprises two faculty (Whitworth and Ward-Thompson), two other post-docs and seven postgrads. The Cardiff Astronomy Programme is also active in the chemical evolution of galaxies, the origin and life-cycle of interstellar dust, high-redshift galaxies, LSBGs, submillimeter instrumentation, and gravitational waves. We have excellent in-house computing facilities.

Applicants should send a CV, statement of research interests and publications list, to reach Prof. Whitworth by 15 November 2003. They should ask three referees to write by the same date. The minimum starting salary is UKPounds 20,311. The starting date should be before July 2004, and appointment will be for two years, with the possibility of extension to four. Informal enquiries can be made by e-mail (or 'phone) to [ant@astro.cf.ac.uk](mailto:ant@astro.cf.ac.uk) (+4429-20874798). Cardiff University is an Equal-Opportunity Employer.

## *New Books*

### **Galactic Star Formation across the Stellar Mass Spectrum**

Edited by J.M. De Buizer and N.S. van der Blik

These are the proceedings of a workshop held by the International Astronomical Observatories in Chile in La Serena, Chile, on 11-15 March 2002. The purpose of the workshop was to join together the most recent observational and theoretical results of Galactic star formation into a coherent picture of how stars form as a function of mass.

The book is divided into the following parts:

1. Structure and Initial Conditions of the Interstellar Medium and Molecular Clouds
2. Initial Mass Function and Star Formation Efficiency
- 3A. Star Formation Theory and Supporting Observations: Low Mass Star Formation
- 3B. Star Formation Theory and Supporting Observations: Intermediate Mass Star Formation
- 3C. Star Formation Theory and Supporting Observations: High Mass Star Formation
- 3D. Star Formation Theory and Supporting Observations: The Influence of High Mass Stars, Magnetic Fields, and Comparative Studies
4. Circumstellar Disks and Their Formation
5. Energetics: Infall, Outflow, Jets, Masers, & Ionizing Radiation
6. Binaries, Multiple Systems, Clusters, and Numerical Simulations
7. Future Star Formation Studies at the International Observatories in Chile

The book contains 70 papers, including the following 9 reviews:

**Structure of Molecular Cloud Cores and the Initial Conditions for Star Formation** *D. Mardones*

**The Stellar Initial Mass Function and Beyond** *R.B. Larson*

**On the Formation of Low Mass Stars** *S. Lizano*

**Intermediate Mass Stars** *L. Testi*

**Theories of Massive Star Formation: Collisions, Accretion and the View from the "I" of Orion** *J.C. Tan*

**Star and Planet Formation Near OB Stars** *J. Bally*

**Triggering Collapse, Magnetic Fields, and Very Low Mass Star Formation** *A.P. Boss*

**The Energetics of Outflow and Infall from Low to High Mass YSOs** *D. Shepherd*

**Dynamical Interactions in Star Formation** *C. Clarke & E. Delgado-Donate*

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# Physics of Star Formation in Galaxies

Edited by F. Palla and H. Zinnecker

These are the lecture notes from the 29th Course of the Swiss Society for Astrophysics and Astronomy, held from 22 to 29 March 1999 near Saas-Fee in Switzerland.

The book contains the following chapters:

**1. Historical Introduction. Star Formation: The Early History** *George Herbig*

**2. Pre-Main Sequence Evolution of Stars and Young Clusters** *Francesco Palla*

2.I. Initial Conditions of Pre-Main Sequence Evolution

2.II. Pre-Main Sequence Evolution

2.III. Physical Processes in PMS Stars

2.IV. PMS Evolution of Clusters and Associations

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