

# THE STAR FORMATION NEWSLETTER

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

No. 37 — 9 Oct 1995

Editor: Bo Reipurth (reipurth@eso.org)

## *From the Editor*

With more than 600 subscribers to the Star Formation Newsletter, it happens regularly that some subscribers change their e-mail addresses, either because they have moved, or due to changes of machine names. Many send me their new address, but some do not. Every month around 15–20 newsletters bounce back due to machines being down, poor connections or addresses that no longer exist. I am trying to keep track of which mails are returned, and if the same address fails three times in a row, and I am not able to locate a new address, I delete it from the mailing list. It is quite an effort to do this, and I therefore ask you to kindly let me know whenever your e-mail address changes. About two dozen subscribers have been removed this way so far, and should you be among them, reading this issue through the WWW, you are welcome to contact me and get back on the mailing list.

## *Abstracts of recently accepted papers*

### **The Gas-Phase Abundances of Heavy Elements and the Destruction of Dust Grains in Herbig-Haro Shock Waves**

**Bernhard Beck-Winchatz<sup>1</sup>, Karl-Heinz Böhm<sup>1</sup> and Alberto Noriega-Crespo<sup>2</sup>**

<sup>1</sup> Dept. of Astronomy, Box 351580, University of Washington, Seattle, WA 98195-1580, USA

<sup>2</sup> Infrared Processing and Data Analysis Center, California Institute of Technology, JPL, Pasadena, CA 91125, USA

E-mail contact: bbeck@astro.washington.edu

The gas-phase abundance ratios Fe/S and Fe/O have been determined for the Herbig-Haro objects HH 1, HH 7, HH 11, HH 43A, and HH 255 (Burnham's Nebula) from a fairly large number of forbidden emission lines. For HH 1, the ratio Ni/S has been determined as well. Our objective was to investigate whether Fe and Ni are depleted by dust formation in the line-emitting regions as is typical for normal (neutral or molecular) interstellar regions, or whether the observed matter has gone through sufficiently fast shock waves so that the dust grains have been destroyed and Fe and Ni have gone back into the gas-phase. Using observationally-determined electron temperatures and densities we have solved the statistical equilibrium equations for Fe<sup>+</sup>, Fe<sup>++</sup>, S<sup>+</sup>, O<sup>0</sup>, O<sup>+</sup>, O<sup>++</sup>, and Ni<sup>+</sup> and calculated the intensities of the respective emissions lines. For Fe<sup>+</sup> a large number of new collision strengths has recently become available which enabled us to include a much greater number of transitions in our calculations than has previously been possible. For HH 1 and HH 7 both ratios Fe/S and Fe/O agree very well with the solar abundance ratios. For HH 11, the more reliable ratio Fe/S is also very close to the solar value, while the less reliable ratio Fe/O is somewhat higher. For HH 43A both abundance ratios suggest an Fe depletion by a factor 2-3 but the result is considered somewhat uncertain. The results for Burnham's Nebula also indicate a depletion of Fe (by a factor of ~3) and are more reliable. We conclude that this object has undergone a dust-formation and shock wave history which is quite different from that of HH 1, HH 7, and HH 11.

The Ni/S abundance ratio determined for HH 1 is a factor ~10 larger than the solar value. The results for the different observed [Ni II] lines are quite consistent. This situation has been found in other gaseous nebulae as well and is still enigmatic.

Accepted by Astron. J.

# Non-Equilibrium Photodissociation Regions: Ionization-Dissociation Fronts

Frank Bertoldi<sup>1</sup> and Bruce T. Draine<sup>2</sup>

<sup>1</sup> Max-Planck-Institut für Extraterrestrische Physik, D-85740 Garching, Germany

<sup>2</sup> Princeton University Observatory, Peyton Hall, Princeton, NJ 08544, USA

E-mail contact: fkb@mpe-garching.mpg.de

We discuss the theory of coupled ionization–dissociation fronts produced when molecular clouds are exposed to  $\lambda < 1110\text{\AA}$  radiation from hot stars. A steady, composite structure is developed, which generally includes an ionized outflow away from the cloud, an ionization front, a layer of photodissociated gas, a photodissociation front, and a shock wave preceding the photodissociation front. We show that the properties of the structure are determined by two dimensionless parameters,  $\psi$  and  $\delta$ , and by the Alfvén speed in the preshock gas. For a broad range of parameters of interest, the ionization front and the hydrogen photodissociation front do not separate, the  $\text{H}_2$  photodissociation and photoionization take place together, and a classical hydrogen “photodissociation region” (PDR) does not exist. We also show that even when a distinct photodissociation region exists, in many cases the dissociation front propagates too rapidly for the usual stationary models of PDRs to be applicable. We discuss several famous PDRs, e.g., in M17 and Orion and conclude that they cannot be described by equilibrium PDR models.

To appear in Ap.J., Feb.10, 1996

# Protostellar Envelopes: A Clue to the Initial Conditions of Star Formation

Ian A. Bonnell, Matthew R. Bate and Nigel M. Price

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK

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

Since the initial conditions for star formation are difficult to ascertain from either observations or theories of molecular clouds, we investigate how the protostellar envelopes that form around young stars depend on the initial conditions for gravitational collapse. For prolate clouds, the evolution depends primarily on whether the cloud’s minor axis,  $R_{min}$ , is smaller or larger than the Jeans Radius,  $R_J$ , the minimum radius to be gravitationally bound. Clouds containing few Jeans Masses (especially those that are centrally condensed) have  $R_{min} \lesssim R_J$  and thus collapse preferentially along the major axis, forcing the cloud to become oblate. Alternatively, clouds containing many Jeans Masses have  $R_{min} \gtrsim R_J$  and thus collapse preferentially along their minor axis, thus increasing their axis ratio and becoming more prolate. When collapse occurs preferentially along the major axis, a large-scale (up to  $10^4$  AU) flattened disc-like structure results as the infalling matter shocks in the equatorial plane. This pseudo-disc forms solely due to the hydrodynamical processes and without either magnetic fields or rotation. Based on these results, we deduce that the presence of prolate envelopes around young stars implies that they were formed from initial conditions containing many Jeans Masses and were thus far from virial equilibrium. Initial conditions of this sort require a dynamical formation mechanism.

Accepted by MNRAS

# A Study of Absorption Features in the Three Micron Spectra of Molecular Cloud Sources with $\text{H}_2\text{O}$ Ice Bands

T. Y. Brooke<sup>1</sup>, K. Sellgren<sup>2</sup>, and R. G. Smith<sup>3</sup>

<sup>1</sup> Jet Propulsion Laboratory, M/S 169-237, 4800 Oak Grove Dr., Pasadena, CA 91109 USA

<sup>2</sup> Department of Astronomy, Ohio State University, 174 West 18th Av., Columbus, OH 43210 USA

<sup>3</sup> Department of Physics, University College, University of New South Wales, Australian Defence Force Academy, 2600 Canberra, Australia

E-mail contact: tyb@scn5.jpl.nasa.gov

New 3.3–3.6  $\mu\text{m}$  spectra were obtained of nine young stellar objects embedded in molecular clouds. An absorption feature at  $\sim 3.47 \mu\text{m}$  ( $2880 \text{ cm}^{-1}$ ) with  $\text{FWHM} \sim 0.09 \mu\text{m}$  ( $80 \text{ cm}^{-1}$ ), first identified by Allamandola et al. (1992), was definitively detected toward seven objects, and marginally in the other two. The feature is better correlated with  $\text{H}_2\text{O}$  ice than with the silicate dust optical depth in the data obtained to date. Assuming the feature is due to a C–H stretch absorption, the abundance of the C–H bonds averaged along the lines of sight is closely related to that

of H<sub>2</sub>O ice. We interpret the correlation with H<sub>2</sub>O ice as indicating that the C–H bonds form together with H<sub>2</sub>O ice on grain surfaces in the molecular clouds, though other formation mechanisms are not ruled out. A second absorption feature at 3.25  $\mu\text{m}$  (3080  $\text{cm}^{-1}$ ) was detected toward NGC7538/IRS 1 and S140/IRS 1; this feature was first detected in spectra of MonR2/IRS 3 (Sellgren, Smith, & Brooke 1994; Sellgren et al. 1995). There is as yet insufficient data to tell whether this feature is better correlated with H<sub>2</sub>O ice or silicates.

Accepted by Ap. J.

## The photospheres of embedded young stellar objects

Mark M. Casali<sup>1</sup>, Carlos Eiroa<sup>2</sup>

<sup>1</sup> Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, UK

<sup>2</sup> Dept. de Fisica Teorica, Facultad de Ciencias, UNAM, 28049, Madrid, Spain

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

We present an extensive study of the infrared ( $\Delta V = 2$ ) CO absorption bands in low-luminosity young stars at intermediate resolutions ( $R \approx 1000$ ), and at high resolution ( $R \approx 17000$ ) for a sub-sample. The bands are very common in YSOs and correlate well with SED class in the sense that Class II sources tend to show CO absorption while Class I sources do not. From the relative band strengths a lower limit on the CO excitation temperature of 2300 K is derived. The echelle spectra show that the majority of CO bandheads are broadened by less than 17  $\text{km s}^{-1}$  and point to a stellar photospheric origin rather than a disk; they also suggest that most YSOs are only slowly rotating. The band strengths are inversely correlated with the thermal infrared excess, which leads to a simple model in which the CO bands from the central PMS star are veiled by continuum emission from circumstellar dust.

Accepted by A & A

## A catalogue of massive young stellar objects

S.J. Chan, Th. Henning, K. Schreyer

MPG–Arbeitsgruppe “Staub in Sternentstehungsgebieten”, Schillergäßchen 2–3, D–07745 Jena, Germany

E-mail contact: henning@fred.astro.uni-jena.de

A catalogue of massive young stellar objects which contains about 250 objects is presented. This catalogue is an updated version of the catalogue of Henning et al. (1984). It will provide comprehensive information on infrared and radio flux densities, molecular line data, association with maser sources, and outflow phenomena.

Accepted by Astron. & Astrophys. Suppl. Ser.

## Vibrational ground state SiO $J=1-0$ emission in Orion IRc2 imaged with the VLA

Claire J. Chandler<sup>1</sup>, and Christopher G. De Pree<sup>2</sup>

<sup>1</sup> National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, USA

<sup>2</sup> Department of Physics and Astronomy, CB3255, The University of North Carolina, Chapel Hill, NC 27599-3255, USA

E-mail contact: cchandle@nrao.edu

We have used the VLA to observe SiO( $v=0$ ,  $J=1-0$ ) at 43.4 GHz in the IRc2 region of Orion with 2'' resolution. Both a thermal and a maser component are detected, making IRc2 the only known star forming region with an SiO vibrational ground state maser. The maser emission is double-peaked, and is extended over  $\sim 900$  AU with the same position angle as that observed for the  $v=1$  masers. The velocity extent of the  $v=0$  masers (30  $\text{km s}^{-1}$ ) is similar to the  $v=1$  SiO, OH and H<sub>2</sub>O masers; we suggest that their motions are dominated by the outflow from IRc2 rather than a rotating disk. The gradient in the thermal component is in the same sense as the CO outflow from IRc2 and appears to trace the interaction region between the IRc2 wind and nearby dense molecular material to the south. The thermal SiO emission is clearly centered on IRc2 and not the hot core.

Accepted by The Astrophysical Journal Letters

## High Resolution Observations of the NGC 2024 Outflows

Lawrence Chernin

Dept of Astronomy, Univ. of California, Berkeley CA 94720, USA

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

We present high spatial resolution ( $4''$ ), fully sampled images obtained by combining observations with the BIMA interferometer and the NRAO 12 m telescope of the CO J=1-0 emission from the outflows in the NGC 2024 FIR 5 and FIR 6 regions. We find a rather complex spatial distribution of molecular outflow emission in this region, and argue that at least three separate sources are driving jet-like molecular outflows. Furthermore, from the positions and orientations of the outflow lobes, it seems unlikely that the outflows are driven by the FIR objects, as had been previously thought. Instead, we propose that the outflows are driven by jets from faint low mass protostars located in the molecular cores adjacent to the FIR objects.

Accepted by *Astrophys. J.*

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

## Clumpiness in molecular clouds and statistics of embedded sources

F. Comerón<sup>1</sup>, J. Torra<sup>1</sup> and G.H. Rieke<sup>2</sup>

<sup>1</sup> Departament d'Astronomia i Meteorologia, Universitat de Barcelona, Av. Diagonal, 647, 08028 Barcelona, Spain

<sup>2</sup> Steward Observatory and Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721, USA

E-mail contact: fcomeron@fajtr0.am.ub.es

Statistical studies of stellar populations embedded in molecular clouds are affected by several potential biases. In this paper we use a simple model of a clumpy molecular cloud to evaluate how star counts, from which volume densities are derived, can be altered by background source contamination and by an incorrect evaluation of the sampled volume in a magnitude-limited survey, due to the clumpiness of the embedding cloud.

Accepted by *Astron. Astrophys.*

## CN Zeeman Observations of Molecular Cloud Cores

Richard M. Crutcher<sup>1</sup>, Thomas H. Troland<sup>2</sup>, Bernard Lazareff<sup>3</sup> and Ilya Kazes<sup>4</sup>

<sup>1</sup> Department of Astronomy, University of Illinois, Urbana, IL 61801, USA

<sup>2</sup> Department of Physics and Astronomy, University of Kentucky, Lexington, KY 40506, USA

<sup>3</sup> IRAM, 300, Rue de la Piscine, Domaine Universitaire, 38406 St-Martin-D'Herès, France

<sup>4</sup> Observatoire de Paris-Section de Meudon, Place Jules Janssen, F-92195 Meudon, France

E-mail contact: crutcher@uiuc.edu

We present results from the first attempt to measure strengths of magnetic fields in dense molecular cloud cores by observations of the Zeeman effect in the 3-mm lines of CN. The observations were made with the 30-m IRAM radiotelescope with a new polarimeter constructed for this experiment. The two molecular cores which were observed are located about 3 arcmin north of Orion-KL (OMC-N4) and about 1 arcmin east of IRS4 in S106 (S106-CN). From CN data for OMC-N4 and S106-CN, respectively, we estimate cloud radii of 0.03 and 0.05 pc, masses of 10 and 22  $M_{\odot}$ , and H<sub>2</sub> densities of  $1.6 \times 10^6$  and  $0.7 \times 10^6$  cm<sup>-3</sup>. Our CN Zeeman results for the line-of-sight magnetic fields are  $B_{los}(\text{OMC-N4}) = +79 \pm 99$   $\mu\text{G}$  and  $B_{los}(\text{S106-CN}) = -57 \pm 199$   $\mu\text{G}$ . Hence, we did not detect magnetic fields. Our upper limits for  $B_{los}$  are significantly less than field strengths expected for assumptions of (1) internal motions at the Alfvén speed, (2) a critical mass to magnetic flux ratio, or (3) virial equilibrium, but the very small sample of clouds and the uncertainties in the Alfvén, critical, and virial estimates of the magnetic field preclude definite conclusions. Additional CN Zeeman observations will be carried out in order to obtain a statistically significant sample of cores.

Accepted by *Astrophys. J.* for January 1, 1996 issue

## A search for molecular gas components in prototypal Vega-excess systems

W.R.F. Dent<sup>1</sup>, J.S. Greaves<sup>1,2</sup>, V. Mannings<sup>3</sup>, I.M. Coulson<sup>1</sup> and D.M. Walther<sup>1</sup>

<sup>1</sup> Joint Astronomy Centre, 660 N. A‘ōhōku Place, Hilo, Hawaii 96720, USA

<sup>2</sup> Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK

<sup>3</sup> Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

E-mail contact: dent@jach.hawaii.edu

We report the results of a deep search for sub-mm lines of  $^{12}\text{CO}$  around the nearby main-sequence stars Vega ( $\alpha$  Lyr),  $\epsilon$  Eridanus, Fomalhaut ( $\alpha$  PsA),  $\beta$  Leo and  $\beta$  Pictoris. Upper limits on CO masses around 10 to 100 times lower than those previously reported have been obtained. If ‘normal’ interstellar medium CO abundances are assumed, the data suggest that the gas:dust mass ratio is reduced by a factor  $\gtrsim 10^3$  below that found in molecular clouds. These *apparently* low values can be explained by photodissociation of CO in the stellar or, in the case of  $\epsilon$  Eri, the interstellar UV radiation field. The *predicted* CO column densities are similar to our limits if the CO is not replenished. Although the  $\beta$  Pic disc has the highest dust mass, the large grain size results in a relatively low UV extinction to the central star, and so CO photodissociation can readily occur. It has been suggested by others that the CO could be replenished by the occasional infall of comets, and we place an upper limit to the rate of cometary accretion for  $\epsilon$  Eri.

Accepted by MNRAS Lett.

## WSRT and VLA Observations of the 6 centimeter and 2 centimeter lines of $\text{H}_2\text{CO}$ in the Direction of W 3

Hélène R. Dickel<sup>1</sup>, W. Miller Goss<sup>2</sup> and G. R. Condon<sup>2,3</sup>

<sup>1</sup> Department of Astronomy, University of Illinois, 1002 West Green Street, Urbana IL 61801, USA

<sup>2</sup> National Radio Astronomy Observatory, P.O. Box O, Socorro NM 87801, USA

<sup>3</sup> Department of Physics and Astronomy, University of New Mexico, 800 Yale Blvd, NE, Albuquerque NM 87131, USA

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

Formaldehyde absorption toward the HII regions in W 3 has been imaged at 6 cm with the Westerbork Synthesis Radio Telescope and at 2 cm with the Very Large Array with an angular resolution of  $\sim 5''$  and a velocity resolution of  $\sim 0.6 \text{ km s}^{-1}$ . The opacities in both transitions are low, ranging between 0.05 and 0.3. The  $\ell$ sr velocities are around  $-39 \text{ km s}^{-1}$  toward the eastern component of the molecular core which includes the HII regions W 3 A and W 3 B and between  $-45 \text{ km s}^{-1}$  toward the western component which includes W 3 C and W 3 D.

The typical line widths are  $1\text{-}3 \text{ km s}^{-1}$  except toward the HII region W 3 D (FWHM  $\sim 5 \text{ km s}^{-1}$ ). For this source, a “champagne flow” at the edge of the molecular cloud may explain both the wide formaldehyde lines and the gradient in the recombination lines.

Typical molecular hydrogen densities are  $\sim 10^5 \text{ cm}^{-3}$ , in agreement with earlier estimates from observations of other molecules. The abundance of formaldehyde relative to molecular hydrogen is  $(1\text{-}2) \times 10^{-9}$  except toward W 3 D where it is  $\geq 5 \times 10^{-9}$ .

The formaldehyde absorption toward the shell-like HII region W 3 A is strongest toward the south/southwest edge of the continuum source and appears to arise from a thin, compressed layer. This layer may have been compressed by the expansion of the ionized gas into part of the eastern molecular core.

Accepted by Astrophysical Journal (preprints are available from H. Dickel, Internet: lanie@astro.uiuc.edu)

## Energetics of star–disc encounters in the non-linear regime

S.M. Hall<sup>1</sup>, C.J. Clarke<sup>2</sup> and J.E. Pringle<sup>1</sup>

<sup>1</sup> Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, U.K.

<sup>2</sup> School of Mathematical Sciences, Queen Mary & Westfield College, Mile End Road, London E1 4NS, U.K.

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

We investigate the response of a circumstellar accretion disc to the fly-by of a perturbing mass on a parabolic orbit. The energy and angular momentum transferred during the encounter are calculated using a reduced three-body method. In almost all close encounters the energy and angular momentum transfer is dominated by disc material becoming

unbound from the system, with the contributions from close disc particle – star encounters being significant. For more distant encounters with some prograde element to the motion the disc material loses energy and angular momentum to the perturber’s orbit through a resonance feature. The magnitude of the energy transfer calculated in our simulations is greater than that of the binding energy of material exterior to periastron by a factor of two in the prograde case, and up to a factor of five in the case of the retrograde encounter. The destructive nature of the encounters indicates that a non-linear treatment is essential in all but the most distant encounters.

Accepted by MNRAS

## The magnetic field structure around protostars: Submillimetre polarimetry of VLA1623 and S106-IR/FIR.

W. S. Holland<sup>1,2</sup>, J. S. Greaves<sup>1,2</sup>, D. Ward-Thompson<sup>2</sup> and P. André<sup>3</sup>

<sup>1</sup> Joint Astronomy Center, 660 N. A’ohoku Place, Hilo, Hawaii 97620, USA

<sup>2</sup> Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK

<sup>3</sup> Service d’Astrophysique, Centre d’Etudes de Saclay, F-91191 Gif-sur-Yvette Cedex, France.

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

We present 800  $\mu\text{m}$  polarization observations of the young low-mass candidate protostar VLA1623, and of the high-mass young stellar object S106-IR and its companion candidate protostar S106-FIR. The polarized emission due to aligned dust grains has been used to derive the magnetic field direction around both sources. In the case of VLA1623 we find that the field direction is almost exactly perpendicular to the extremely well-collimated CO outflow. This suggests that the large-scale magnetic field in the cloud cannot be responsible for the collimation of the outflow. However, the data may be consistent with a recent magneto-hydrodynamic model where the field follows stream lines through the central plane of a ‘cored apple’ accretion structure. In S106 our observations indicate a magnetic field along the dust lane connecting the IR/FIR sources, and perpendicular to the bipolar HII region. A model consistent both with these data, and previous Zeeman measurements, is presented, in which the large-scale magnetic field is poloidal, but is either twisted into a toroidal morphology, or highly ‘pinched-in’, in the flattened dust lane.

We also present a synopsis of recent submillimetre polarimetry observations of young disk/outflow sources. For high-mass objects, the data are consistent with super-critical collapse models, and there is evidence for varying degrees of field compression. There is also a correlation of net field orientation with source distance, which is explained by the inclusion of varying amounts of ambient cloud material within the telescope beam. For the few low-mass objects for which data is available, the polarization is less affected by ambient material, and there is some evidence that different outflow models may apply in different sources.

Accepted by Astron. & Astrophys.

## Three Millimeter Continuum Studies of Sagittarius B2

Yi-Jehng Kuan<sup>1,2</sup>, David M. Mehringer<sup>1</sup> and Lewis E. Snyder<sup>1</sup>

<sup>1</sup> Department of Astronomy, University of Illinois, Urbana-Champaign, IL 61801, USA

<sup>2</sup> Institute of Astronomy & Astrophysics, Academia Sinica, Taipei, Taiwan 115, ROC

E-mail contact: kuan@biaa3.biaa.sinica.edu.tw

Continuum emission at 4.9, 8.3, 78.5, 81.5, 84.9, 87.9, 106.9 and 109.9 GHz was observed in Sgr B2. Spectral indices near 3 mm are  $\alpha = -0.31 \pm 0.03$  and  $-0.2 \pm 0.2$  for Sgr B2(N’) and Sgr B2(W), respectively, and are attributed to the optically thin free-free emission. Free-free emission contributes significantly to the 3 mm continuum in Sgr B2(M), but the positive slope of the continuum spectrum ( $\alpha = 1.0 \pm 0.3$ ) indicates the presence of dust grains. Sgr B2(N) is dominated by thermal dust emission with a steep spectral index  $\alpha = 4.6 \pm 0.5$ .

The 3 mm continuum spectra yield the grain emissivity exponents  $\beta = 1.7 \pm 1.3$  and  $3.7 \pm 0.7$  for Sgr B2(M) and Sgr B2(N), respectively. The grain emissivity law derived for Sgr B2(N) is significantly higher than most for other molecular clouds. Thus, Sgr B2(N) appears to be a very unusual dust core. The most likely explanation is that the region contains ice coated core-mantle grains. The existence of ice coated core-mantle grains implies the mean dust temperature in the Sgr B2(N) dust core is  $< 150$  K. The short life time of the core-mantle phase and the high value of  $N_{H_2}$  indicate that Sgr B2(N) is quite young and in a very early stage of star formation.

Accepted by The Astrophysical Journal

# The Structure and Energetics of A Highly Collimated Bipolar Outflow: NGC 2264G

Charles J. Lada<sup>1</sup> and Michel Fich<sup>2</sup>

<sup>1</sup> Smithsonian Astrophysical Observatory, MS 72, 60 Garden Street, Cambridge, MA 02138, USA

<sup>2</sup> Physics Department, University of Waterloo, Waterloo Canada, N2L 3G1

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

We present a detailed observational study of  $^{12}\text{CO}$  ( $J = 2 \rightarrow 1$ ) emission from the spectacular bipolar molecular outflow NGC 2264G. These observations enable significantly improved determinations of the basic physical parameters of the outflow and reveal rich structural detail in both its spatial morphology and velocity field. We identify a number of robust physical characteristics of the outflow which provide critical challenges for the development of a theoretical understanding of the dynamical nature of this and other bipolar molecular outflows. In particular, we find that: 1) the velocity field of the outflow is described by a single ‘‘Hubble’’ law to a remarkable degree of precision over its entire extent, 2) the flow exhibits a high degree of bipolarity with an intensity contrast between red and blue emission in each lobe of at least a factor of 20 indicating that the motion of gas in the outflow is strongly (forwardly) directed along the flow major axis, 3) the flow exhibits a well behaved, power-law variation of mass with velocity, and 4) the collimation of the flow increases systematically with flow velocity and distance from the driving source, with the highest velocity gas very jet-like in appearance. Moreover, at the highest flow velocities the two oppositely directed lobes display a high degree of similarity in their basic physical properties suggesting that the underlying wind driving the outflow is characterized by an intrinsic bipolar symmetry which originates with the driving engine at the origin of the outflow. Existing outflow theory cannot yet account for the constraints imposed by these observations. In particular, we find the general result that bow shock models cannot produce the degree of bipolarity required to match the observations of this and other outflows. Improved estimates of the outflow’s mass, size and energetics provide strong constraints on the energetics of the driving engine.

Accepted by The Astrophysical Journal

## A Search for Precursors of Ultracompact HII Regions in a Sample of Luminous IRAS Sources. I: Association with Ammonia Cores

S. Molinari<sup>1,2,3</sup>, J. Brand<sup>1</sup>, R. Cesaroni<sup>4</sup> and F. Palla<sup>4</sup>

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

<sup>2</sup> Università degli Studi di Bologna, Via Zamboni 33, 40126 Bologna, Italy

<sup>3</sup> Istituto di Fisica dello Spazio Interplanetario-CNR, Via G. Galilei, CP 27, 00044 Frascati, Italy

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

E-mail contact: molinari@astbo1.bo.cnr.it

We present observations of  $\text{NH}_3$  (1,1) and (2,2) lines in two flux-limited samples of IRAS sources selected according to colour criteria which should result in a high fraction of Young Stellar Objects. The first sample contains sources (named ‘lo’) whose evolutionary status is essentially unknown, while the second sample contains sources (named ‘hi’) possibly associated with ultracompact HII regions, the distinction being based on the IRAS [25–12] colour. Indications from a previous study of  $\text{H}_2\text{O}$  maser emission suggest that the sources in the first group may be in an evolutionary phase prior to the appearance of an HII region, thus being among the youngest known high-mass forming objects.

‘lo’ sources were detected in ammonia with a lower rate than ‘hi’ sources (45% and 80% respectively); the only difference between the two groups is in the linewidths: the (1,1) lines are generally narrower than (2,2) lines in ‘hi’ sources (FWHMs median values are 1.81 km/s and 2.00 km/s respectively), while the opposite is true in ‘lo’ sources (FWHMs median values are 1.72 km/s and 1.33 km/s for the (1,1) and (2,2) lines respectively). We propose that the ‘lo’ group consists of two distinct populations of evolutionary different objects, based on the (non-) association with ammonia emission. The ‘lo’ sources showing ammonia emission are characterized by more quiescent envelopes than those surrounding ‘hi’ sources, and the relationships between relevant physical quantities derived from our observations and the IRAS colours suggest that ‘hi’ sources, contrary to ‘lo’, may harbour objects which dominate the physical and dynamical properties of the clump, thus possibly implying the relative youth of this subgroup of the ‘lo’ sources.

Accepted by Astronomy & Astrophysics

# CO ( $J=2-1$ ) Line Observations of the Galactic Center Molecular Cloud Complex: I. On-Plane Structure

Tomoharu Oka<sup>1,2</sup>, Tetsuo Hasegawa<sup>2</sup>, Masahiko Hayashi<sup>1,3</sup>, Toshihiro Handa<sup>2</sup> and Seiichi Sakamoto<sup>1,3</sup>

<sup>1</sup> Department of Astronomy, Faculty of Science, University of Tokyo, Hongo 7-1-1, Bunkyo-ku, Tokyo 113, Japan

<sup>2</sup> Institute of Astronomy, Faculty of Science, University of Tokyo, Osawa 2-21-1, Mitaka, Tokyo 181, Japan

<sup>3</sup> National Astronomical Observatory, Osawa 2-21-1, Mitaka, Tokyo 181, Japan

E-mail contact: tomo@nro.nao.ac.jp

We present results of a mapping observation of the Galactic center region in the CO ( $J=2-1$ ) line at 230 GHz, using the Tokyo-NRO 60 cm survey telescope (9' beam). The CO ( $J=2-1$ )/CO ( $J=1-0$ ) intensity ratio,  $R_{(2-1)/(1-0)}$ , exceeds unity for the Galactic center molecular gas with bright CO emission.

The intermediate density ( $n(\text{H}_2) \geq 10^3 \text{cm}^{-3}$ ) molecular gas traced by CO ( $J=2-1$ ) line shows highly asymmetric pattern in the  $l$ - $V$  plane. This asymmetry appears more prominently in CS and  $\text{NH}_3$  line emissions which probe denser molecular gas. Nevertheless, sites of recent massive star formation traced by Hydrogen recombination lines (HII regions) and evolved intermediate mass stars traced by OH maser emission (OH/IR stars) show a relatively symmetric pattern in the  $l$ - $V$  plane. This simple kinematics indicates that star formation have been taking place, continuously or intermittently, in a region about 100 pc in radius (Star Forming Ring). A closer comparison shows that the HII regions have systematically lower velocities (in absolute values) than the OH/IR stars. If the kinematics of OH/IR stars reflect the galactic gravitational potential, this difference can be understood as a result of bisymmetric distribution of the HII regions. A possible interpretation is that the outer region of the Star Forming Ring is near the 1st inner Lindblad resonance (ILR), where molecular gas accumulates in two arms to be self-gravitating and intense star formation is triggered, as we see as "twin peaks" in the central regions of barred galaxies. This small ILR radius requires the existence of small scale ( $\sim 1\text{kpc}$ ), rapidly rotating bar in the central region of the Galaxy.

We calculated the intensity ratio between our CO ( $J=2-1$ ) data and the CO ( $J=1-0$ ) data taken with Columbia 1.2 m telescope. The average ratio for the gas at  $-3^\circ \leq l \leq +3^\circ$  within 4.5' (10 pc) from the galactic plane is  $0.74 \pm 0.02$ . Regions with  $R_{(2-1)/(1-0)} \geq 1.2$  are found along the high velocity side of the CO emission. The cloud complex located close to Sgr A\* (Sgr A molecular cloud complex), which contains well-known two giant clouds – 20  $\text{km s}^{-1}$  and 40  $\text{km s}^{-1}$  clouds – exhibit extremely high intensity ratio  $R_{(2-1)/(1-0)} \simeq 1.4$ . An anti-correlation is seen in the  $l$ - $V$  diagram between the gas with high ratio ( $R_{(2-1)/(1-0)} \geq 1.2$ ) and HII regions ( $R_{(2-1)/(1-0)} \sim 1$ ). The observed large  $R_{(2-1)/(1-0)}$  exceeding unity can be interpreted as different sizes of "photospheres" for the two lines in clumps that compose the Galactic center clouds.

Accepted by Ap. J.

## Shocked molecular hydrogen emission in the bipolar outflow NGC 6334 I

P.Persi<sup>1</sup>, M.Roth<sup>2</sup>, M.Tapia<sup>3,4</sup>, A.R.Marenzi<sup>1</sup>, M.Felli<sup>5</sup>, L.Testi<sup>6</sup> and M.Ferrari-Toniolo<sup>1</sup>

<sup>1</sup> Istituto Astrofisica Spaziale, CNR, CP.67, 00044 Frascati, Italy

<sup>2</sup> Las Campanas Observatory, Carnegie Institution of Washington, Casilla 601, La Serena, Chile

<sup>3</sup> Instituto de Astronomia UNAM, Apdo. Postal 877, Ensenada, B.C. 22830, Mexico

<sup>4</sup> Royal Greenwich Observatory, Madingley Rd., Cambridge, CB3 0EZ, UK

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

<sup>6</sup> Dip.Astronom.e Scienza dello Spazio, Universita' di Firenze, Italy

E-mail contact: persi@saturn.ias.fra.cnr.it

Sub-arcsec images in the J, H, K, and  $\text{H}_2$  and nearby continuum of the bipolar outflow NGC 6334 I are presented. Three knots of  $\text{H}_2$  emission are found which coincide with recently discovered  $\text{NH}_3(3,3)$  masers. Two of these are aligned along the CO bipolar outflow, indicating that the hydrogen molecular emission is shock excited. We have also detected a loop-shaped infrared nebula extending to the east of the massive mid-infrared source IRS1 which illuminates the reflection nebula. IRS1 consists of at least four components in the near-infrared. The interaction of the stellar wind from these young stellar objects with the surrounding medium could excite the third  $\text{H}_2$  emission knot and associate ammonia maser.

Accepted by Astron. Astrophys.



# Axisymmetric Two-Dimensional Computation of Magnetic Field Dragging in Accretion Disks

Mauricio Reyes-Ruiz<sup>1,2</sup> and Tomasz F. Stepinski<sup>3</sup>

<sup>1</sup> Department of Space Physics and Astronomy, Rice University, Houston, TX 77005, USA

<sup>2</sup> Present address: Observatorio Astronómico Nacional, Apdo Postal 877, Código Postal 22860 Ensenada, B.C., Mexico

<sup>3</sup> Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston, TX 77058, USA

E-mail contact: maurey@bufadora.astrosen.unam.mx

In this paper we model a geometrically thin accretion disk interacting with an externally imposed, uniform, vertical magnetic field. The accretion flow in the disk drags and distorts field lines, amplifying the magnetic field in the process. Inside the disk the radial component of the field is sheared into a toroidal component. The aim of this work is to establish the character of the resultant magnetic field and its dependence on the disk's parameters. We concentrate on  $\alpha$ -disks driven by turbulent viscosity. Axisymmetric, two-dimensional solutions are obtained without taking into account the back-reaction of the magnetic field on the structure of the disk. The character of the magnetic field depends strongly on the magnitude of the magnetic Prandtl number,  $\mathcal{P}$ . We present two illustrative examples of viscous disks: a so-called "standard" steady-state model of a disk around a compact star (e.g. cataclysmic variable), and a steady-state model of a protoplanetary disk. In both cases,  $\mathcal{P} = 1$ ,  $\mathcal{P} = 10^{-1}$ , and  $\mathcal{P} = 10^{-2}$  scenarios are calculated. Significant bending and magnification of the magnetic field is possible only for disks characterized by  $\mathcal{P}$  of the order of  $10^{-2}$ . In such a case, the field lines are bent sufficiently to allow the development of a centrifugally driven wind. Inside the disk the field is dominated by its toroidal component. We also investigate the dragging of the magnetic field by a nonviscous protoplanetary disk described by a phenomenological model. This scenario leads to large distortion and magnification of the magnetic field.

Accepted by Astrophysical Journal

# Radio Continuum Detection of the Exciting Sources of the DG Tau B and L1551 NE Outflows

Luis F. Rodríguez<sup>1</sup>, Guillem Anglada<sup>2</sup> and Alejandro Raga<sup>1</sup>

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

<sup>2</sup> Departament d'Astronomia i Meteorologia, Universitat de Barcelona, Av. Diagonal 647, E-08028 Barcelona, Spain

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

The exciting sources of molecular outflows are characteristically associated with centimeter radio continuum emission, most probably originating in a partially ionized, collimated outflow. DG Tau B and L1551 NE are two low-luminosity pre-main-sequence objects that have been found recently to be associated with molecular outflows. We have used 3.5-cm Very Large Array observations with angular resolution of  $0''.2$  to detect compact radio continuum sources at both the positions of DG Tau B and L1551 NE. The DG Tau B radio source has deconvolved dimensions  $0''.38 \pm 0''.02 \times 0''.22 \pm 0''.02$  and its major axis is aligned along a position angle of  $298^\circ \pm 5^\circ$ , coincident within a few degrees with the position angle of the axis of the optical and molecular outflows ( $\sim 294^\circ$ ). This result suggests that we are observing the base of the collimated jet that powers the region, on scales of tens of astronomical units. A comparison of the widths of the radio and optical jets in this source supports this interpretation.

Accepted by Ap. J. Letters, Dec. 10, 1995 issue

# The disruption of molecular cloud cores by photoionization

J.A. Rodríguez-Gaspar<sup>1</sup>, G. Tenorio-Tagle<sup>1</sup> and J. Franco<sup>2</sup>

<sup>1</sup>Instituto de Astrofísica de Canarias, 38200-La Laguna, Tenerife. Spain (jrg@ll.iac.es, gtt@ll.iac.es)

<sup>2</sup>Instituto de Astronomía, UNAM, Apdo. Postal 70-264, México D. F., México. (pepe@astroscu.unam.mx)

E-mail contact: jrg@ll.iac.es

We solve the line transfer problem in evolving HII regions in order to calculate line profiles of hydrogen recombination ( $H_\alpha$ ) and forbidden oxygen (OIII) lines along several lines of sight during the photodisruption of molecular cloud cores, or high density condensations. The density, velocity and ionization structure of spherically symmetric models with an

initial power law density distribution,  $\rho \propto r^{-w}$ , were used to calculate the source function. We differentiate between two possible evolutions: the classic evolution ( $w \leq 1.5$ ) which upon expansion of the ionized gas a shock is driven into the neutral intercloud medium, and secondly, for steeper density gradients ( $w > 1.5$ ), where the Champagne phase develops as the whole cloud becomes ionized by a supersonic R-type ionization front. Thus a strong shock is driven into the ionized gas by the expansion of the denser cloud core. The rapid expansion of these high density cores generates supersonic outflows as well as important variations in the HII equilibrium temperature. This ranges from  $10^3$  K within the core to  $8 \cdot 10^4$  K behind the Champagne shocks. As a result, the line profiles in these cases may present a partial or total splitting both in  $H_\alpha$  and in [OIII]  $\lambda 5007\text{\AA}$ . Also the surface brightness distributions of the oxygen line footprints mainly the hot ( $T > 3 \cdot 10^4$  K) and fast moving shocked gas, and the  $H_\alpha$  traces the slower purely photoionized matter ( $T \sim 10^4$  K). Thus, the continuous and rapid disruption of condensations, driven by the pressure imbalance set through photoionization within a star forming cloud, adds a supersonic bulk motion to the uniform velocity field expected from the classical evolution.

Accepted by the Astrophysical Journal

## A Numerical Study of Magnetic Buoyancy in an Accretion Disk

M. Różyczka<sup>1,2</sup>, P. Bodenheimer<sup>3</sup>, and D. N. C. Lin<sup>3</sup>

<sup>1</sup> Warsaw University Observatory, Al. Ujazdowskie 4, PL-00478 Warszawa, Poland

<sup>2</sup> Nicolaus Copernicus Astronomical Center, Bartycka 18, PL-00716 Warszawa, Poland

<sup>3</sup> UCO/Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, CA 95064, USA

We follow the evolution of a closed loop of relatively weak poloidal magnetic field, originally embedded somewhat above the midplane in a hydrostatic accretion disk. The equations of magnetohydrodynamics are solved on a numerical grid in axisymmetric geometry. Viscous heating, radiative transfer, and the horizontal and vertical components of the gravity of the central star are taken into account. As the evolution proceeds, toroidal field is built up as a result of shear in the disk, and the field becomes buoyant as a result of interchange modes of the Parker instability. The effective wavelength of the buoyant instability, and its dependence on the strength of the initial field loop, are found to be consistent with a linear stability analysis. The buoyancy results in turbulent motions and expulsion of some field from the disk. Eventually, a saturation state is reached, in which the field assumes a patchy structure, and the ratio of gas to magnetic pressure stabilizes in the range 1-5. Outward angular momentum transfer and an accompanying radial expansion of the magnetized region occur as a result of magnetic torques, and an equivalent  $\alpha$ -viscosity parameter is estimated. The implications of these results on the generation of a magnetic dynamo in a disk are discussed.

Accepted by Astrophys. Journal

## Far-Outer Galaxy H II Regions

Alexander L. Rudolph<sup>1,2</sup>, Jan Brand<sup>3</sup>, Eugène J. de Geus<sup>4,5</sup> and Jan G. A. Wouterloot<sup>6</sup>

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

<sup>2</sup> Department of Physics, Harvey Mudd College, Claremont, CA 91711, USA

<sup>3</sup> Istituto di Radioastronomia, CNR, Via Gobetti 101, I-40129 Bologna, Italy

<sup>4</sup> Department of Astronomy, University of Maryland, College Park, MD 20742, USA

<sup>5</sup> Present address: Astronomy Department, Caltech 105-24, Pasadena, CA 91125, USA

<sup>6</sup> I. Physikalisches Institut, Zùlpicher Strasse 77, D-50937 Köln, Germany

We have made a multiwavelength (6, 3.6, and 2 cm), high-resolution ( $3''$ – $6''$ ), radio continuum survey of IRAS-selected sources to search for and study H II regions in the far-outer Galaxy. We identified 31 sources with  $R \geq 15$  kpc and  $L_{\text{FIR}} \geq 10^4 L_\odot$ , indicating the presence of high-mass star-formation.

We have observed 11 of these sources with the Very Large Array (VLA). The 6 and 2 cm observations were made using “scaled arrays”, making possible a direct and reliable determination of spectral indices. Of the 39 sources we detected at 6 cm, 10 have spectral indices consistent with optically-thin free-free emission from H II regions, and are within  $45''$  of the associated IRAS source. Combining our data with previous VLA observations by other investigators, we analyze a sample of 15 of the most remote H II regions found in our Galaxy, located at  $R = 15$  to 18.2 kpc.

The sizes of the H II regions range from  $\leq 0.10$  to 2.3 pc. Using the measured flux densities and sizes, we determine

their electron densities, emission measures, and excitation parameters, as well as their Lyman continuum fluxes needed to keep the nebulae ionized. The sizes and electron densities indicate that most of the sources are (ultra)compact H II regions.

Seven of the fifteen H II regions have sizes  $\leq 0.20$  pc. The large number of compact H II regions suggests that the time these regions spend in a compact phase must be much longer than their dynamical expansion times.

Five of the fifteen H II regions have cometary shapes; the remainder are spherical or unresolved. Comparison of our data with molecular line maps suggests that the cometary shape of the two H II regions in S 127 may be due to pressure confinement of the expanding ionized gas, as in the “blister” or “champagne flow” models of H II regions. Comparison of our data with the IRAS data indicates that the five most luminous H II regions are consistent with a single ZAMS O or B star exciting a dust-free H II region.

Accepted by Ap.J.

## **NH<sub>3</sub> and HCO<sup>+</sup> towards luminous IRAS sources**

**K. Schreyer<sup>1</sup>, Th. Henning<sup>1</sup>, C. Kömpe<sup>2</sup>, and P. Harjunpää<sup>3</sup>**

<sup>1</sup> MPG–Arbeitsgruppe “Staub in Sternentstehungsgebieten”, Schillergäßchen 3, D–07745 Jena, Germany

<sup>2</sup> Universitäts–Sternwarte, Schillergäßchen 2, D–07745 Jena, Germany

<sup>3</sup> Helsinki University Observatory, Tähtitorninmäki, SF–00130 Helsinki, Finland

E-mail contact: martin@fred.astro.uni-jena.de

We have selected 67 objects for observation that are presumably massive young stellar objects. They were from the IRAS Point Source Catalogue based on their infrared flux ( $F_\nu \geq 500$  Jy at  $100 \mu\text{m}$ ). All objects have been surveyed in the NH<sub>3</sub> (1,1) and (2,2) lines, and a subsample of 53 objects in the rotational line of HCO<sup>+</sup> ( $J=1-0$ ). 25 objects (37 %) were detected in the NH<sub>3</sub> (1,1) line, 18 objects (27 %) in the NH<sub>3</sub> (2,2) line, and 38 objects (72 %) in the HCO<sup>+</sup> line. Two objects, IRAS 06058+2138 and IRAS 06061+2151, have been mapped in the two ammonia transitions. From the molecular line data, we have derived the kinetic temperature  $T_{\text{kin}}$  and the NH<sub>3</sub> column densities. These data were combined with data from the literature and data derived from the IRAS fluxes (dust colour temperature  $T_{\text{d}}$ , optical depth  $\tau$ , luminosity). No clear correlations were found; the data are, however, consistent with least square fits found by Wouterloot et al. (1988a). The probability to detect H<sub>2</sub>O maser sources is strongly correlated with the detection of NH<sub>3</sub> emission: Water maser emission has been seen towards 83 % of those objects with clear detections of NH<sub>3</sub> (1,1) and (2,2) lines.

Accepted by Astron. & Astrophys.

## **The formation of ‘bullets’ via hydrodynamical instabilities in stellar outflows**

**James M. Stone, Jianjun Xu, and Lee G. Mundy**

Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA

High resolution images of young stars and supernova remnants often reveal structures which are interpreted as “bullets” ejected by the source, i.e. small, high density knots of gas which propagate supersonically into the surrounding ambient material. Understanding how these bullets are created and accelerated to high velocity without disruption is a long standing puzzle. An alternate point of view, however, is that the bullets condense *in situ* in the high velocity gas via hydrodynamical processes. Such mechanisms have been identified as producing condensations in supernova ejecta, and may also operate in planetary nebula. Here, we demonstrate similar processes can form bullets in poorly collimated winds from young stars. Thus, bullets associated with outflow sources should not be interpreted as accelerated by explosive events at the source, rather they are a natural consequence of the interaction of the outflowing gas with a radiatively cooled ambient medium.

To appear in Nature

## The remarkable Herbig Ae star V351 Ori = HD 38238

M.E. van den Ancker, P.S. Thé and D. de Winter

Astronomical Institute “Anton Pannekoek”, University of Amsterdam, Kruislaan 403, NL-1098 SJ Amsterdam, The Netherlands

E-mail contact: mario@astro.uva.nl

The photometric behaviour of the irregular variable Herbig Ae star V351 Ori was investigated combining data from the literature with new photometric data in the Strömgren system. It is shown that this enigmatic object changed its photometric behaviour from that of a Herbig Ae star with strong photometric variations, due to extinction by circumstellar dust clouds, to that of an almost non-variable star. Such a behaviour is not unique; it has been found also in the star BN Ori (Shevchenko et al. 1995). This suggests that such transitions must occur quite often during the evolution of intermediate mass HAeBe stars towards the main-sequence (MS). However, it is equally probable that before such a star arrives at the MS, it will become strongly variable again after collecting enough dust from its environment.

During the process of V351 Ori’s transition from a Herbig Ae star with strong photometric variations to a non-variable one, the maximum brightness in the Strömgren  $v$ ,  $b$  and  $y$  magnitudes decreased, whereas that in  $u$  increased, causing a strong blueing effect in the colour-magnitude diagrams. It should be noted that this effect happened at a decrease in visual brightness by about  $0^m.2$  magnitude only. It is therefore caused by a different mechanism than that in V351 Ori before the transition and in UX Ori type stars, where the blueing effect occurs at a decrease in  $V$  of about  $2^m.5$ .

The transition, from a strongly variable star to the state in which V351 Ori is nearly constant at a level equal to that of its maximum brightness before the transition, happened very fast (within 50 days), and went along the interstellar reddening line in the colour-magnitude diagrams. A provisional model to explain V351 Ori’s behaviour, in which it is assumed that a temporarily strong accretion of matter onto the star took place, is proposed.

Accepted by Astronomy & Astrophysics

A preprint of this paper is available via WWW at <http://www.astro.uva.nl/preprints/preprints.html>

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. You can either access it via the ESO Portal (<http://http.hq.eso.org/eso-homepage.html>) or directly in two ways: by issue number (<http://http.hq.eso.org/star-form-news1/star-form-list.html>) or via a wais index ([wais://http.hq.eso.org:2010/starform](http://http.hq.eso.org:2010/starform)). You can also access it through the University of Massachusetts Astronomy World Wide Web server, the URL for its home page is <http://www-astro.phast.umass.edu/>

*Dissertation Abstracts*

**The Evolution of Dust in the Terrestrial Planet Region of Circumstellar Disks Around Young Stars**

**Diane Dutkevitch**

Thesis work conducted at: Five College Astronomy Department, University of Massachusetts, Amherst

Current address: Dearborn Observatory, Northwestern University, 2131 Sheridan Road, Evanston, IL 60208-2900, USA

Electronic mail: [diane@annie.astro.nwu.edu](mailto:diane@annie.astro.nwu.edu)

Ph.D dissertation directed by: Michael F. Skrutskie

Ph.D degree awarded: May 1995

Circumstellar disks with masses comparable to the primeval solar nebula have been discovered around numerous pre-main sequence stars; it is believed the disks are a natural byproduct of star formation. If most stars originally have massive circumstellar disks, it is very likely planetary systems are common. Orbiting planets are not directly observable owing to their relatively cool temperatures and meager surface area. However, in the early stages of planetary formation, the surface area of debris in the disk may exceed the surface area of the star by many orders of magnitude. Material in the terrestrial zone emits primarily at near-infrared wavelengths; sufficient disk debris may produce detectable excess emission at these wavelengths. As clearing mechanisms, including possible planetary formation, remove the small particles in the disk, the strong infrared emission diminishes. By observing the excess infrared emission as a function of stellar age and spectral type, timescales for inner disk processes which create or remove small particles can be established.

This dissertation presents sensitive, simultaneous, near-infrared broadband continuum observations of old pre-main sequence and young main-sequence cluster stars. The stellar ages range from 1-600 Myr, spanning the predicted epoch of planetary formation for solar-type stars. A wide range of spectral types were observed. We detect no excess emission after an age of about  $3 \times 10^6$  yr.

Using a model to predict the infrared emission from an optically thin dust disk, we find our measurements are sensitive to  $10^{20}$  -  $10^{21}$  g of micron-radius dust grains ( $= 2 \text{ g cm}^{-3}$ ) distributed within the terrestrial zone. Adapting this result to a more realistic particle size distribution, we believe we can detect debris in extra-solar systems until the terrestrial planets are 90-95% complete.

Older models of the formation of the Earth which assume orderly growth predict the Earth is 90% complete after about 80 Myr. Newer models allow runaway growth, which shortens the timescale to  $\sim 10^5$  yr. If the observed clearing in the inner disk reflects the formation of terrestrial planets, our results strongly support models of planetary formation which incorporate runaway growth. Implications are discussed.

This thesis is available on the World Wide Web at:

<http://decoy.phast.umass.edu/>

## *Meetings*

### **IAU Symposium 178**

## **Molecules in Astrophysics: Probes & Processes**

**Leiden, The Netherlands, July 1–5 1996**

Topics include:

- Molecules in star-forming regions
- Physics and chemistry of shocks, PDR's and masers
- Molecules in circumstellar disks, solar nebula connection
- Comets and the Jupiter impact
- Diffuse and translucent clouds
- Molecules in nearby galaxies and at high redshift
- Chemistry in circumstellar envelopes around late-type stars
- Basic molecular processes

This conference is organized by the IAU working group on Astrochemistry: L.W. Avery, L. Blitz, R.D. Brown, A. Dalgarno, E.F. van Dishoeck (secretary), J.M. Greenberg, A. Hjalmarsson, W. Irvine, H. Kroto, A. Léger, Y.C. Minh, P.D. Singh, L.E. Snyder, S.P. Tarafdar, T. Tsuji, D.A. Williams (chair), Q. Zheng.

For further information and preliminary registration, send e-mail to: [symp96@strw.leidenuniv.nl](mailto:symp96@strw.leidenuniv.nl) with the subject line: send-info. See also WWW <http://www.strw.leidenuniv.nl/~symp96> or contact Symposium 1996, Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands. Fax: +31-71-527-5819.

# THE INTERACTION OF STARS WITH THEIR ENVIRONMENT

advanced spring school and workshop  
to be held in Visegrád, Hungary, 23 - 25 May, 1996  
organized by  
the Section of Astronomy of the Eötvös Loránd Physical Society (SAELPS)

The school is part of a series of biennial autumn schools organized by the SAELPS. The site of the meeting is the town of Visegrád, a resort place about 20 km from Budapest among scenic hills, on the Danube. The venue of the meeting will be the resort hotel of the Eötvös University in Visegrád. The town is easily accessible from Budapest by coach, car or boat. The school will last 3 days + 1/2 day excursion.

The character of these schools is very informal, typically with ca. 40 participants. They are organized around theoretical and experimental tools and physical concepts useful in many branches of astronomy, thereby helping “interdisciplinary” communication between astronomers working in diverse fields. Participants range from students to professors. Emphasis is on review talks given by experts in the topic of the school from different areas of astronomy and on free discussion and exchange.

Visit our WWW page at: <http://enlil.elte.hu/vise/visegrad1.html>

Topics to be covered (further propositions are welcome):

- STAR FORMATION
- SOLAR AND STELLAR WINDS
- SUPERNOVA REMNANTS

A preliminary list of invited speakers so far:

John Bally	John Dyson
Luke Drury	Yuri Efremov
Péter Király	Tom Millar
Garrelt Mellema	Antonella Natta
Werner Pfau	Tom Ray
John Richer	Vladimir Surdin
Károly Szegő	Gábor Tóth
Malcolm Walmsley	Igor Zinchenko

Speakers are welcome, but the restricted time may force us to select among applicants; the main selection criterion should be the relevance of the proposed talk to the main subject of the school. If you wish to give a talk, please enclose a short abstract.

Members of the local organizing committee are the leading members of the SAELPS. Chair: Dr L.G. Balázs (Konkoly Obs.); Secretary: L.V. Tóth (Eötvös Univ., Dept. of Astronomy)

For further information please contact:

**TÓTH, L. Viktor**

Eötvös University, Department of Astronomy  
Budapest  
Ludovika tér 2  
H-1083 Hungary  
Tel.: (36-1-)1141019  
Fax: (36-1-)2101089  
E-mail: [lvtoth@innin.elte.hu](mailto:lvtoth@innin.elte.hu)