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## *Abstracts of recently accepted papers*

### **Molecular material and young stellar objects in the L1188 dark cloud complex**

**Péter Ábrahám<sup>1</sup>, Kazuhito Dobashi<sup>2</sup>, Akira Mizuno<sup>3</sup> and Yasuo Fukui<sup>3</sup>**

<sup>1</sup> Konkoly Observatory of the Hungarian Academy of Sciences, P.O. Box 67, H-1525 Budapest, Hungary

<sup>2</sup> Materials Science, University of Osaka Prefecture, Sakai 593, Osaka, Japan

<sup>3</sup> Department of Astrophysics, Nagoya University, Chikusa-ku, Nagoya 464-01, Japan

E-mail contact: abraham@ogyalla.konkoly.hu

We present a study on the molecular distribution and star formation in L1188, a dark cloud complex in Cepheus. The spatial distribution of dust particles, derived from IRAS maps, indicates that L1188 is physically connected to the nearby S140 region, therefore we adopt the distance of S140, 910 pc, as that of L1188. This connection also indicates that L1188 may belong to the Cepheus Bubble, a giant ring around the Cep OB2 association. <sup>13</sup>CO observations have been performed with the 4 m radiotelescope at Nagoya University, covering a field of 74' × 44' around L1188. Six molecular clumps are found in the observed region, and for each clump physical parameters such as excitation temperature, peak H<sub>2</sub> column density, and molecular mass are derived, as well as the clumps' virial stability is investigated. The total mass of the complex is estimated to be ~ 1800 M<sub>⊙</sub>. We have carried out an optical photographic survey for H $\alpha$  emission line stars with the Schmidt telescope at Konkoly Observatory, and found 15 T Tau candidate stars in the L1188 region, 10 of which seem to be associated with molecular emission regions. We also searched for YSOs in the IRAS Point Source Catalog, and selected 6 young objects close to the cloud.

The number of young infrared sources having  $L_{\text{IR}} > 10L_{\odot}$  per solar mass was found to be relatively high in L1188 in comparison with other dark cloud complexes, indicating low-to-intermediate mass star formation in this cloud. The YSO candidates show a highly inhomogeneous spatial distribution: they are associated with clumps located at the lower galactic longitude part of the complex. Clumps with star formation have been found to have slightly higher excitation temperatures, more negative radial velocities, and narrower <sup>13</sup>CO line profiles, than those without star formation.

Accepted by Astron. Astrophys.

### **Magnetic cycles and photometric variability of T Tauri stars**

**Philip J. Armitage**

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

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

We consider the effects of stellar magnetic cycles on disc accretion in T Tauri stars where the inner region of the disc is disrupted by the stellar field. Using time-dependent disc models, we show that order unity variations in field strength can strongly modulate the accretion flow for cycle time-scales of years to decades. Photometric variability is expected to be greatest in the ultraviolet, with smaller but still significant variations probable in the near-infrared. We suggest that variable stellar magnetic fields may contribute to the long-time-scale photometric variability of T Tauri stars. The long-term variability of T Tauri stars may therefore provide a clue to the nature of magnetic dynamo cycles in these stars.

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# An extremely-high-velocity multipolar outflow around IRAS 20050+2720

R. Bachiller<sup>1</sup>, A. Fuente<sup>1</sup> and M. Tafalla<sup>2</sup>

<sup>1</sup> Centro Astronómico de Yebes (OAN, IGN), Apartado 148, E-19080 Guadalajara, Spain

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

E-mail contact: bachiller@cay.es

We report high-angular resolution maps in the CO 2→1 and CS 3→2 lines of the molecular gas around the embedded object IRAS 20050+2027. This is a 260  $L_{\odot}$  source located in the Cygnus Rift at 700 pc from the Sun. The CS data uncover a dense core of size 0.3 pc, and 80  $M_{\odot}$  centered on the IRAS object. The CO map reveals a remarkable molecular outflow consisting of three pairs of lobes emanating from the close vicinity of the IRAS source. One of the lobe pairs is a highly-collimated jet of extremely high-velocity emission (LSR velocities up to  $\pm 70$  km/s) containing molecular “bullets”.

We briefly examine different possibilities to explain the complex structure of the multipolar outflow. A single outflow appears unable to explain all the CO observations, so we suggest that two or three independent outflows emanate from different young sources embedded within the core.

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## Numerical simulation of 2D jets with time-dependent direction of ejection

S. Biro<sup>1,2</sup>, A.C. Raga<sup>3,2</sup> and J. Cantó<sup>1</sup>

<sup>1</sup> Astronomy Dept., The University, Manchester M13 9PL, U.K.

<sup>2</sup> Instituto de Astronomía, UNAM, Apdo. Postal 70-264, México D.F. 04510, Mexico

<sup>3</sup> Mathematics Dept., UMIST, P.O. Box 88, Manchester M60 1QD, U.K.

Jets from young stars often show sinuous structures or apparent changes of direction in the plane of the sky. These effects can be interpreted as being the direct consequence of a time-dependent direction of ejection from the source.

To analyze this possible interpretation we have computed adiabatic and nonadiabatic 2D jets from sources with a time-dependent ejection direction. From these numerical simulations, we have obtained a qualitative description of the general characteristics of such flows. We have also obtained emission line intensity maps which appear to share at least some of the observational characteristics of stellar jets.

A simulation of the complete structure of an adiabatic wiggling jet is presented. From it we extract information about the general structure, velocities, the shock formation and evolution, knot formation and motion and finer structure at the head of the jet. A “close-up” of the body of a non-adiabatic wiggling jet is also presented. Maps of emission from this flow are calculated and compared with observational data.

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## Collapse and Fragmentation of Molecular Cloud Cores. III. Initial Differential Rotation

Alan P. Boss<sup>1</sup> and Elizabeth A. Myhill<sup>1,2</sup>

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

<sup>2</sup> Marymount University, Arlington, Virginia, USA

Fragmentation during protostellar collapse is the leading mechanism for explaining the formation of binary and multiple stars. Most calculations of protostellar fragmentation have assumed the initial molecular cloud cores to be in solid body rotation, whereas differential rotation might characterize some molecular cloud cores. Here we use a second-order accurate, radiative hydrodynamics code to calculate the self-gravitational collapse of three-dimensional protostellar clouds, starting from centrally condensed (Gaussian), prolate (1.5:1 and 2:1 axis ratios) configurations, with varying degrees of differential rotation. The initial differential rotation is characterized by an exponent  $\gamma_i$  specifying the dependence of the initial angular velocity profile on the initial density ( $\Omega_i \propto \rho_i^{\gamma_i}$ );  $\gamma_i = 0$  produces initially solid body rotation, while  $\gamma_i = 2/3$  results in the maximum degree of differential rotation consistent with spherical contraction at conserved mass and angular momentum. Depending on the value of  $\gamma_i$ , and the initial ratios of thermal ( $\alpha_i$ ) and rotational ( $\beta_i$ ) to gravitational energy, three types of outcomes result: slow contraction, vigorous collapse without fragmentation, or collapse leading to fragmentation. Fragmentation occurs for  $\gamma_i = 2/3$  clouds with initial 1.5:1 axis

ratios when  $\alpha_i < 0.45$  and  $\beta_i \approx 0.1$ , whereas  $\gamma_i = 0$  clouds only fragment for  $\alpha_i < 0.3$ . For initial 2:1 axis ratios, fragmentation requires  $\alpha_i < 0.5$  and  $\beta_i \approx 0.1$  for  $\gamma_i = 2/3$ , compared to  $\alpha_i < 0.4$  for clouds with  $\gamma_i = 0$ . These criteria quantify the extent to which initial differential rotation enhances rotationally-driven fragmentation by concentrating the angular momentum per unit mass in the densest regions of the cloud. Gaussian clouds in rapid differential rotation can fragment even if they start collapse from a configuration close to virial equilibrium ( $\alpha_i + \beta_i = 1/2$ ).

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## IRAS Sources Beyond the Solar Circle. V. Properties of Far-Outer Galaxy Molecular Clouds.

J. Brand<sup>1</sup>, J.G.A. Wouterloot<sup>2</sup>

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

<sup>2</sup> I. Physikalisches Institut, Zülpicher Str. 77, D 50937 Köln, Germany

The properties of star-forming clouds at the edge of the galactic molecular disk (far-outer Galaxy: FOG) are analyzed. By adding data from the literature, we compare the inner- and outer Galaxy (separated at  $R = R_0 = 8.5$  kpc) cloud populations.

Applying a radiation transfer model to multi-line CO observations of two FOG clouds,  $T_{kin}$ 's between about 6 K and 15 K are derived, comparable to those of clouds at smaller  $R$ . A statistical analysis of  $T_A^*$  both of clouds without embedded heating sources, and of clouds associated with IRAS sources, confirms there is no evidence for a gradient in cloud temperatures across the Galaxy for  $R > 8.5$  kpc.

The column density of  $H_2$ , as derived from  $N(H_2) = X \times W_{CO}$  ( $= \int T_R^* dv$ ), and the  $H_2$  LTE column density show a reasonable agreement for  $X = 2.3 \cdot 10^{20} \text{ cm}^{-2} (\text{Kkms}^{-1})^{-1}$  (derived for the inner Galaxy), if the LTE analysis takes into account a galactic gradient of  $(H_2/^{13}\text{CO})$ . The average and median values of  $X = N_{lte} / \int T_R^* dv$ ,  $3.3 \pm 1.7 [1\sigma]$  and  $2.9 \cdot 10^{20}$  respectively, then are within 30–45% of the inner Galaxy value. Due to saturation effects the average  $X$  increases from  $3 \cdot 10^{20}$  ( $W_{CO} \leq 20$ ) to  $6 \cdot 10^{20} \text{ cm}^{-2} (\text{Kkms}^{-1})^{-1}$  ( $W_{CO} > 40 \text{ Kkms}^{-1}$ ).

Including data from the literature we have a sample of 204 molecular clouds with  $3 \lesssim R \lesssim 20$  kpc. Assuming  $X = 2.3 \cdot 10^{20}$  for all inner- and outer Galaxy clouds we find separate, nearly parallel relations in diagrams of  $\log M_{Wco}$  versus  $\log r_A$  and  $\log \Delta v$  versus  $\log r_A$ . Although part of the offset of a factor of 2 in  $r_A$  may be due to the difficulties related to the identification of inner Galaxy clouds, it may be mainly explained by inner Galaxy clouds having a higher density, or by a variation of  $X$  with  $R$  (or with mass). We find  $M_{Wco} \propto r_A^{2.0 \pm 0.1}$  for all clouds, and  $\Delta v \propto r_A^{0.48 \pm 0.04}$  (inner) and  $\propto r_A^{0.53 \pm 0.03}$  (outer).

Inner- and outer Galaxy clouds define a single relation in a diagram of  $\log L_{CO}$  versus  $\log \Delta v$ :  $L_{CO} \propto \Delta v^{3.91 \pm 0.12}$ . This is in contrast to published results where an offset is found between clouds inside and outside the solar circle. We conclude that a diagram of CO luminosity versus line width is not a good instrument to determine whether there is a dependence of  $X$  on  $R$ .

The mass spectrum for all outer Galaxy molecular clouds in the extended sample with  $M_{Wco} \gtrsim 3.75 \cdot 10^4$  is  $dN/dM_{Wco} \propto M_{Wco}^{-1.62 \pm 0.04}$ . For all 204 clouds, the slope is  $-1.79 \pm 0.03$ .

The average ratio of virial- to  $W_{CO}$ -mass of all clouds is  $1.4 \pm 1.3 (1\sigma)$ , with a possible dependency on  $R$  and/or mass: there are indications that the ratio increases for clouds at larger  $R$ , or for clouds of smaller mass, but the cloud-cloud variations are large. Most clouds in the sample could be in equilibrium through confinement by external pressure. All clouds can be made to be in virial equilibrium, by allowing  $X$  to change by a factor of 4 between  $R \approx 4$  and 20 kpc. This would require the galactic abundance gradient to be steeper than what is expected from an extrapolation of the presently available data.

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## The Influence of Magnetic Fields on Star Formation

S.E. Byleveld and H. Pongracic

Research Centre for Theoretical Astrophysics, School of Physics, University of Sydney, Australia

E-mail contact: sueb@physics.usyd.edu.au, helenp@physics.usyd.edu.au

Numerical simulations suggest that colliding molecular clouds induce gravitational collapse and may be responsible for star formation. We incorporate magnetic fields in these simulations and present preliminary results of an investigation of the influence of magnetic fields on star formation via this process.

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## A Test Case of Stellar Evolution: the Eclipsing Binary EK Cephei

Antonio Claret<sup>1</sup>, Antonio Giménez<sup>2</sup>, and Eduardo L. Martín<sup>1</sup>

<sup>1</sup> Instituto de Astrofísica de Canarias, La Laguna, E-38200 Tenerife, Spain

<sup>2</sup> Laboratorio de Astrofísica Espacial y Física Fundamental, INTA, Apartado 50727, E-28080 Madrid, Spain

E-mail contact: ege@iac.es

EK Cep is a double-lined eclipsing binary system with unique characteristics. Accurate absolute dimensions are available, a good determination of the surface lithium abundance has been made, the system is known to show apsidal motion variations, and its secondary seems to be in the pre-main sequence phase. Due to all this, it appears to be a very good candidate to test predictions made on the basis of currently adopted stellar evolutionary models.

We have carried out a comparison of the observed parameters of EK Cep with theoretically predicted values, and we have found that an evolutionary age for the binary system around  $2 \times 10^7$  years verifies that both components are on the same isochrone. Moreover, the secondary component has been confirmed as a pre-main sequence star while the primary is in the beginning of the hydrogen-burning phase. For the same evolutionary age, we computed the theoretical internal structure constants of the component stars and thus predicted the newtonian apsidal motion rate. The relativistic contribution is expected to be quite large (around 40% of the total value) due to the small relative radii of the two stars. For the present paper, a new determination of the observational motion rate has been made with a result of  $0.00101 \pm 0.00015$  degrees per cycle. This is in perfect agreement with the predicted total value. On the other hand, lithium depletion was followed during the computation of the models. For the primary component we found no depletion, and for the secondary the predicted depletion was only 0.1 dex which is in good agreement with observations.

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## Herbig–Haro Outflows in the V380 Orionis Region

D. Corcoran and T.P. Ray

School of Cosmic Physics, Dublin Institute for Advanced Studies, Ireland

E-mail contact: tr@cp.dias.ie

We report the discovery of a remarkable emission line “loop” to the west of V380 Ori. This “loop”, taken together with the known and some newly found Herbig–Haro (HH) objects, appears to delineate a poorly collimated optical outflow from this source. The optical outflow complements a redshifted molecular outflow to the east of V380 Ori implying an overall east-west outflow axis. Although V380 Ori is classified as a Herbig Ae/Be (HAEBE) star, it shows LiI $\lambda$ 6708 in absorption suggesting the additional presence of a T-Tauri star. In this regard, it is interesting that Leinert et al. (1994), using near-infrared speckle interferometry, have recently found V380 Ori to be a double. It seems unlikely, however, that the T Tauri star is responsible for the outflow.

In the area around V380 Ori, two other optical outflows were investigated, HH 130 and the newly discovered HH 147. The bow-shaped HH 130 was previously thought to be an isolated object but we show here that it is part of an extended ( $\geq 0.7$ pc) outflow and demonstrate that it could be driven by a “light” jet. HH 147 is particularly interesting in that its source, a T-Tauri star, is found to exhibit a P-Cygni profile in H $\alpha$ . HH 147 itself appears to contain both highly and poorly collimated outflow components.

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## The Sagittarius B2 Star Forming Region: II. High Resolution H66 $\alpha$ Observations of Sgr B2 North

C. G. De Pree<sup>1,2</sup>, R. A. Gaume<sup>3</sup>, W. M. Goss<sup>1</sup> and M. J. Claussen<sup>1</sup>

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

<sup>2</sup> Department of Physics and Astronomy, University of North Carolina at Chapel Hill, USA

<sup>3</sup> US Naval Observatory, 3450 Massachusetts Ave. NW, Washington, DC 20392-5420, USA

E-mail contact: cdepree@nrao.edu

We have observed the Sagittarius B2 (Sgr B2) North star-forming region with the Very Large Array in the continuum (1.3 cm) and in the radio recombination lines H66 $\alpha$  and He66 $\alpha$ . Sgr B2 North contains regions of ionized gas ranging in size from unresolved ( $d < 0.01$  pc) to extended ( $d \sim 0.5$  pc), and thus presents an ideal laboratory to study the effects of circumstellar environments on HII region evolution. The H66 $\alpha$  data provide high spatial (0.25'') and spectral (10 km s<sup>-1</sup>) resolution kinematics of the ionized gas associated with massive stars. The helium and hydrogen data are used together as a high resolution probe of Y<sup>+</sup> values and variations within Sgr B2. In Sgr B2 North, we measure a helium abundance of  $\langle Y^+ \rangle = 13 \pm 1\%$ . We present the H66 $\alpha$  and He66 $\alpha$  results from Sgr B2 K, and the nearby sources L, R and X. Region K consists of six subregions, one of which (K6) has a continuum morphology and a double-peaked spectral line consistent with an expanding shell of ionized gas ( $v_{exp} \sim 22$  km s<sup>-1</sup>). We detect no radio recombination line emission ( $\frac{T_L}{T_C} < 3\%$ ) from the ultracompact HII region K2, which is cospatial in projection with the dynamical center of a bipolar molecular outflow imaged in HC<sub>3</sub>N (Lis et al. 1993). The recombination line velocities of K1 and K3 agree with the N-S rotation in molecular gas observed by Lis et al. (1993). Source L is an ‘‘arc-like’’ region with a large velocity gradient of  $\sim 70$  km s<sup>-1</sup> pc<sup>-1</sup> perpendicular to its edge brightened rim. The large velocity gradient at this orientation observed in Sgr B2 L may be due to rotation of the ionized gas around  $\sim 150$ -200 M $_{\odot}$ , consisting of low mass stars.

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## Further mapping of the radio emission from massive young stellar objects

Melvin G. Hoare<sup>1</sup> and Simon T. Garrington<sup>2</sup>

<sup>1</sup> Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

<sup>2</sup> University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank, Lower Withington, Cheshire, SK11 9DL, U.K.

We present high resolution radio maps at a frequency of 1.6 GHz made with the MERLIN array of the luminous young stellar objects Cep A 2 and LkH $\alpha$  101. The elongation seen previously in Cep A 2 appears to extend even further in our map supporting a jet interpretation for the morphology of this source. We discuss this and alternative mechanisms in the context of the large scale outflows in the Cep A region. The 1.6 GHz map of LkH $\alpha$  101 is more symmetric, although it does show a bright bar of emission at a position angle of about 135° plus other extended structures. This map is compared with the previous ones and overall the ionized wind from this object appears to be far from homogeneous.

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## A Multiwavelength Picture of the AFGL 5142 Star-forming Region

Todd R. Hunter<sup>1</sup>, Leonardo Testi<sup>2</sup>, Gregory B. Taylor<sup>1</sup>, Marcello Felli<sup>3</sup>, Gianni Tofani<sup>3</sup> and Thomas G. Phillips<sup>1</sup>

<sup>1</sup> California Institute of Technology, Mail Code 320-47, Pasadena, CA 91125, USA

<sup>2</sup> Dipartimento di Astronomia e Scienza dello Spazio, Università di Firenze, Largo E. Fermi 5, I-50125 Firenze, Italy

<sup>3</sup> Arcetri Astrophysical Observatory, Largo E. Fermi 5, I-50125 Firenze, Italy

E-mail contact: hunter@tacos.caltech.edu

We present molecular line, H<sub>2</sub>O maser, radio continuum and near infrared maps of the bipolar outflow source AFGL 5142. The high resolution of our molecular CO observations enables us to define the morphology of the large-scale bipolar outflow into a two lobe structure extending for  $\sim 2'$  on each side of the center. In the perpendicular direction, we find consistent evidence for a second, more compact ( $< 0.5'$ ) outflow in the form of a spatial velocity offset

in the CO map and of an H<sub>2</sub> jet-like structure derived from a near infrared narrow band image. On a smaller scale size, the radio and infrared continuum observations reveal the engines of the molecular outflows. The maser emission occurs near the position of the most embedded source of the cluster, IRS1. This is located at the center of the compact outflow and jets of shocked H<sub>2</sub> and coincides with an ultra compact radio continuum source (most probably an ionized stellar wind). The H<sub>2</sub>O cluster is composed of five spatial components: two are within 0.2–0.3 arcsec from the YSO (a few hundred AU) and three are at larger distance (1.5–2 arcsec, a few thousand AU). A marginal detection of proper motion of the two more distant masers may suggest a high expansion velocity at a distance  $4 \times 10^3$  AU from the YSO, similar to what is found in Orion KL and W49N. The brightest NIR source of the cluster (IRS2) is associated with an IRAS point source and lies along the axis of the large-scale bipolar outflow. We propose that the masers and the compact molecular outflow are powered concurrently by the wind from the YSO associated with IRS1, while the large scale outflow could be the remnant from the formation of IRS2.

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## Thermal Structure of Mixing Layers in Bipolar Outflows

Susana Lizano<sup>1</sup> and Carlo Giovanardi<sup>2</sup>

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

<sup>2</sup> Osservatorio Astrofisico di Arcetri and CAISMI-C NR, Largo E. Fermi 5, I-50125 Firenze, Italy

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

Assuming that molecular outflows from young low-mass stars are driven by fast neutral atomic winds, we further explore the possibility that these winds interact with the ambient cloud through entrainment of molecular material. This paper is aimed to determine the energy balance and the resulting thermal structure of the entrainment region.

We model the entrainment region as a mixing layer along the walls of a cavity within the cloud itself. We make use of the 21 cm HI spectral profiles observed in L1551 to specify a priori the overall geometry of the flow and the amount of entrainment at each point. Assuming momentum conservation in the layer, we determine – in a single parcel approximation – the radial temperature profile of the mixing layer.

We find that, with a reasonable choice of assumptions, the temperature in these regions is between 3000 and 5000 K. This results from heating due to the dissipation of wind kinetic energy as it decelerates outward due to mass entrainment, and from cooling by ro-vibrational emission of molecular hydrogen. We find that, because of the low density, short crossing time, and replenishment from the cloud, the H<sub>2</sub> is not dissociated and acts as the main coolant in the layer. Even taking into account non-thermal impacts, due to the low density, the thermal coupling between gas and dust is low and results in much lower dust temperatures (10-20 K) through most of the mixing layer. For the same reason dust is not an effective coolant. In the case of L1551 the H<sub>2</sub> emission from the mixing layer, e.g., in the  $v = 1 - 0 S(1)$  line, should be spread over most of the CO lobes and within the detection limits of current (arcmin resolution) near-infrared spectrographs.

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## Spatially-Resolved Mid-Infrared Observations of Circumstellar Dust Around AB Aurigae

Kenneth A. Marsh<sup>1</sup>, Jeffrey E. Van Cleve<sup>2</sup>, M. J. Mahoney<sup>3</sup>, T. L. Hayward<sup>4</sup> and J. R. Houck<sup>5</sup>

<sup>1,3</sup> Jet Propulsion Laboratory, MS 246-101, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

<sup>2,4,5</sup> Astronomy Department, Cornell University, Ithaca, New York 14853-6801, USA

E-mail contact: kam@ipac.caltech.edu

The Herbig Ae star, AB Aur, was observed at wavelengths of 11.7  $\mu\text{m}$  and 17.9  $\mu\text{m}$  using the Cornell SpectroCam-10 imaging spectrometer on the 5-m Hale Telescope. The observed images were deconvolved using a Bayesian estimator which provided superresolution from the incorporation of prior information (the positivity of intensity and the finite support of the emission); this yielded an angular resolution of  $\sim 0.2''$ , which subtends  $\sim 30$  AU at a distance of 160 pc. Our deconvolved images have resolved the source at both wavelengths, and show source diameters of approximately 40 AU and 80 AU at 11.7  $\mu\text{m}$  and 17.9  $\mu\text{m}$ , respectively. At 11.7  $\mu\text{m}$ , the source exhibits some complex structure which has been confirmed using observations on two separate observing runs and different observing techniques; one

characteristic of this structure is the presence of a central depression. The source appearance is markedly different at  $17.9\ \mu\text{m}$ , and is characterized by a central component which is flanked by a pair of weaker, diametrically-opposed features suggestive of an edge-on disk. We hypothesize that such a disk surrounds a tenuous, roughly spherical cloud which produces the silicate emission feature and which dominates the  $11.7\ \mu\text{m}$  emission.

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## Submm polarimetric observations of NGC1333 IRAS4A and 4B: tracing the circumstellar magnetic field

Nigel R. Minchin<sup>1</sup>, Göran Sandell<sup>2</sup>, and Alexander G. Murray<sup>1</sup>

<sup>1</sup> Department of Physics, Queen Mary and Westfield College, Univ. of London, Mile End Road, London E1 3NS, U.K.

<sup>2</sup> Joint Astronomy Centre, 660 N. A'ohōkū Pl., Hilo, HI 96720 U.S.A

E-mail contact: N.R.Minchin@qmw.ac.uk

We have measured the  $800\ \mu\text{m}$  polarization at the flux peak for both NGC1333 IRAS4A and 4B. The polarization position angle is similar for both sources ( $132^\circ \pm 3^\circ$  for 4A and  $100^\circ \pm 10^\circ$  for 4B) and are aligned with the plane of the  $800\ \mu\text{m}$  extended emission plateau that contains the two sources and orthogonal to the CO outflow axis for 4A (position angle  $\sim 42^\circ$ ). The observed polarization position angles imply the dust grains are preferentially aligned along the plane of the extended dust ridge, implying the magnetic field is orthogonal to the dust disk and aligned with the direction of the large scale molecular outflows. Therefore, within the resolution of these observations (14 arcsec FWHM) the circumstellar magnetic fields around IRAS 4A and 4B appear *poloidal*.

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## A submillimetre continuum study of S140/L1204: The detection of three new submillimetre sources and a self-consistent model for the region

Nigel R. Minchin<sup>1</sup>, Derek Ward-Thompson<sup>2</sup> and Glenn J. White<sup>1</sup>

<sup>1</sup> Department of Physics, Queen Mary and Westfield College, Univ. of London, Mile End Road, London E1 3NS, U.K.

<sup>2</sup> Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, U.K.

E-mail contact: N.R.Minchin@qmw.ac.uk

We present submillimetre continuum observations of the L1204/S140 complex in broad bands centred at 450, 800 and  $1100\ \mu\text{m}$ . The morphology of the region is similar at all three wavelengths, with the emitting region compact, about 90 arcsec in diameter, and centrally peaked around the cloud core. Three new submillimetre continuum sources are observed which are not coincident with any previously known near or mid-infrared sources. We designate the sources S140-SMM1–3. SMM1 is roughly coincident with a previously known  $\text{NH}_3$  clump and 2.7mm source, and near-ir reflection nebulosity from the surface of SMM2 has previously been seen. The three submillimetre continuum sources may be protostellar in nature, although it is not possible to determine whether they are gravitationally bound, since virial mass estimates are disrupted by the presence of an energetic bipolar outflow. For this reason, earlier claims that the 2.7mm source in SMM1 is collapsing appear somewhat premature. The observation that SMM1 and SMM2 lie either side of the infrared sources, in a line roughly perpendicular to the direction of the bipolar outflow, imply they may be the remnants of a large-scale disk.

Comparison of the continuum emission with previous high resolution CS,  $\text{NH}_3$  and CI observations provides evidence that, for the first time, demonstrates the photon-dominated region and outflow are intimately linked. The only scenario that is able to explain all of the available molecular and atomic emission line data and our submillimetre continuum data, is one in which the outflow has expanded towards the edge of the molecular cloud and the edge of the blueshifted outflow lobe is now bounded by the expanding HII region. The  $\text{NH}_3$  and continuum emission emanate from the inner edge of the outflow lobe, shielded from the external UV field.

A plot of the  $800\ \mu\text{m}$  flux against  $\text{N}(\text{C}^{18}\text{O})$  implies that the dust/gas mass ratio is close to the canonical value ( $\sim 1\%$ ) at the lower end of the observed extinction range ( $A_v \leq 70$ ), but for the highest observed extinctions ( $A_v = 70\text{--}100$ ) the continuum flux density increases rapidly, implying a higher dust/gas mass ratio is appropriate ( $\sim 2\text{--}5\%$ ), possibly indicating freeze-out of gas onto dust grains.

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# $^{13}\text{CO}$ and $\text{C}^{18}\text{O}$ observations of S140 – delineation of the outflow structure, a study of fractionation effects and comparison with CI observations

Nigel R. Minchin<sup>1</sup>, Glenn J. White<sup>1</sup> and Derek Ward-Thompson<sup>2</sup>

<sup>1</sup> Department of Physics, Queen Mary and Westfield College, University of London, Mile End Road, London E1 3NS, U.K.

<sup>2</sup> Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, U.K.

E-mail contact: N.R.Minchin@qmw.ac.uk

The outflow and photon-dominated region (PDR) associated with the S140 complex have been observed at high resolution ( $\sim 14$  arcsec) in the  $^{13}\text{CO}$  and  $\text{C}^{18}\text{O}$   $J = 3 \rightarrow 2$  lines. The  $\text{C}^{18}\text{O}$  map confirms earlier  $\text{C}^{17}\text{O}$   $J = 3 \rightarrow 2$  line observations (Minchin *et al.* 1994) that show an ‘arc’ of emission observed to the south of the peak, and also reveals a similar (and more prominent) arc feature to the east, a region not covered by the  $\text{C}^{17}\text{O}$  map. This is a particularly fine example of the classic ‘tuning fork’ morphology, where emission at the ambient cloud velocity is tracing the outflow cavity wall of the blueshifted lobe. The  $N(^{13}\text{CO})/N(\text{C}^{18}\text{O})$  ratio has been plotted against extinction and fits the power law relation  $N(^{13}\text{CO})/N(\text{C}^{18}\text{O}) = 21A_v^{-0.35}$ . The highest values, as expected, occur for observed positions towards the PDR, with  $N(^{13}\text{CO})/N(\text{C}^{18}\text{O})$  exceeding the terrestrial value (5.5) for  $A_v \leq 40$  magnitudes. In the outermost parts of the cloud ( $A_v \leq 10$  magnitudes) the  $N(^{13}\text{CO})/N(\text{C}^{18}\text{O})$  ratio is largest, up to 20. The increased fractionation may be due to higher photoionization of the optically thinner isotope,  $\text{C}^{18}\text{O}$ . There is a close correlation between  $N(\text{CI})/N(\text{CO})$  and visual extinction over a wide extinction range ( $A_v = 3\text{--}100$  mags.). The best fit power law is  $N(\text{CI})/N(\text{CO}) = 4.2A_v^{-0.9}$ . For positions toward the outflow ( $A_v \sim 50\text{--}100$ )  $N(\text{CI})/N(\text{CO}) \sim 0.1$  (0.07–0.12).  $N(\text{CI})/N(\text{CO})$  increases with decreasing extinction to  $\sim 1$  for  $A_v \leq 5$  mags., corresponding to positions near the edge of the cloud.

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## Infrared Imaging of Herbig-Haro Energy Sources

Andrea Moneti<sup>1</sup> and Bo Reipurth<sup>2</sup>

<sup>1</sup> SERCo/ESTEC-SAI, Postbus 299, 2200 AG Noordwijk, The Netherlands

<sup>2</sup> European Southern Observatory, Casilla 19001, Santiago 19, Chile

E-mail contact: amoneti@iso.estec.esa.nl

We present near-infrared ( $1\text{--}2.5\mu\text{m}$ ) images of fields near the Herbig-Haro objects HH 24, HH 34, HH 43, HH 83, HH 89, HH 91, and HH 124, which have been obtained in order to search for their energy sources and to determine the location of the latter relative to the Herbig-Haro objects themselves, to measure their near-infrared colors, and to study their immediate environments. We provide J, H, and K photometry of the sources, and discuss their near-infrared energy distribution with the aid of a J-H vs. H-K diagram. Energy sources for all but HH 91 were detected and studied. Those of HH 89 and of HH 124 are new detections, the source HH 83 IRS is found to be better aligned with the HH 83 jet than previously thought, and HH 34 IRS has brightened by about 0.5 mag in all filters. In HH 91 the bright knot where the energy source was expected was found to have colors typical of pure  $\text{H}_2$  emission. All of the energy sources are intimately associated with nebulosity.

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# Hydromagnetic Waves and the Linewidth-Size Relation in Interstellar Molecular Clouds

Telemachos Ch. Mouschovias and Dimitrios Psaltis

Departments of Physics and Astronomy, University of Illinois, 1002 West Green street, Urbana, IL 61801, USA

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

Large-amplitude, long-wavelength Alfvén waves in self-gravitating, magnetically supported clouds imply a linewidth-size relation  $(\Delta v)_{\text{wave}} \simeq 1.4 (B/30\mu\text{G})^{1/2} (R/1 \text{ pc})^{1/2} \text{ km s}^{-1}$ , where  $B$  is the mean magnetic field strength and  $R$  the radius of the cloud. This relation is in excellent quantitative agreement with observations of objects (clouds, cores, and OH masers) for which the nonthermal linewidth  $(\Delta v)_{\text{NT}}$ , the FWHM size  $R$ , and the field strength  $B$  have been measured.

Accepted by The Astrophysical Journal (Letters)

# The Mass of a Star Formed in a Cloud Core: Theory and Its Application to the Orion A Cloud

Takenori Nakano<sup>1</sup>, Tetsuo Hasegawa<sup>2</sup> and Colin Norman<sup>3</sup>

<sup>1</sup> Nobeyama Radio Observatory, National Astronomical Observatory, Nobeyama, Minamisaku, Nagano 384-13, Japan

<sup>2</sup> Institute of Astronomy, University of Tokyo, Osawa, Mitaka, Tokyo 181, Japan

<sup>3</sup> Department of Physics and Astronomy, Johns Hopkins University, and Space Telescope Science Institute, Baltimore, MD 21218, U. S. A.

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

We have investigated the mechanisms of determining the stellar mass in the process of star formation. Because the stellar core grows by the inflow of matter from the parent cloud core, the mass of the growing star is fixed when supply of matter from the cloud core is stopped. Because the cloud core matter falls onto the stellar core mostly through an accretion disk, a significant fraction of the mass outflow from the stellar vicinity and the stellar radiation escapes from the inner region without interacting with the infalling matter. A considerable fraction of the cloud core matter which has not yet contracted much is blown off by the mass outflow and the HII region developed by the stellar ultraviolet radiation. Although some cloud core matter may remain at this stage, it disperses soon because it is no longer gravitationally bound. Consequently supply of matter to the accretion disk and then to the stellar core stops. The stellar mass  $M_*$  determined in this way is a function of the density of the cloud core,  $n_c$ , the mass inflow rate from the cloud core,  $\dot{M}_I$ , the mass outflow rate relative to the inflow rate,  $\dot{M}_O/\dot{M}_I$ , and the cloud core mass relative to the generalized Jeans mass,  $M_c/M_J$ , and can also be represented as a function of  $n_c$ ,  $M_c$ ,  $\dot{M}_O/\dot{M}_I$ , and  $M_c/M_J$ . When the mass outflow is dominant in blowing off the cloud core matter, we have  $M_* \propto M_c^{7/6} n_c^{1/12}$  with the proportionality coefficient dependent on  $\dot{M}_O/\dot{M}_I$ , and thus the stellar mass is almost independent of  $n_c$ . The star formation efficiency  $M_*/M_c$  is therefore mainly determined by  $\dot{M}_O/\dot{M}_I$  and is only weakly dependent on the core parameters  $M_c$  and  $n_c$ ; for a typical value  $\dot{M}_O/\dot{M}_I = 0.1$  we obtain  $M_*/M_c \approx 0.04$  around  $M_c \sim 100M_\odot$ . Applying this method to the observed cloud cores in the Orion A molecular cloud by assuming that each core does not contain subclumps we estimate the stellar mass and the initial mass function of stars (IMF) expected in this cloud. As long as  $\dot{M}_O/\dot{M}_I > 0.02$ , the mass outflow is more efficient than the HII region in determining the stellar mass for all the Orion A cores. The IMF at  $M_* \geq 4M_\odot$  can be approximated by a power law  $dN_*/d\log M_* \propto M_*^{-1.7}$  for  $\dot{M}_O/\dot{M}_I = 0.1$ , which is in reasonable agreement with the IMF of field stars  $\propto M_*^{-1.5}$  at  $M_* \geq 3M_\odot$ . We also discuss star formation in the cloud core which contains many subclumps.

Accepted by Astrophys. J.

## **An Out-of-Plane CO ( $J=2-1$ ) Survey of the Milky Way. I. The Data**

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

<sup>1</sup> Institute of Astronomy, University of Tokyo, Mitaka, Tokyo 181, Japan

<sup>2</sup> Department of Astronomy, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan

<sup>3</sup> Present address: National Astronomical Observatory, Mitaka, Tokyo 181, Japan

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

We present extensive CO ( $J=2-1$ ) survey data of the first quadrant of the Galaxy taken with the same angular resolution as the Columbia CO ( $J=1-0$ ) survey. The CO ( $J=2-1$ ) data were compared with the CO ( $J=1-0$ ) data of Cohen, Dame, & Thaddeus. The distribution of CO ( $J=2-1$ ) emission mimics that of CO ( $J=1-0$ ) emission with the CO ( $J=2-1$ )/CO ( $J=1-0$ ) intensity ratio ( $\equiv R_{2-1/1-0}$ ) of 0.66 averaged over the observed area. This value is typical of nearby giant molecular clouds and of gas disks of spiral galaxies and is consistent with the CO emission arising from subthermally excited, optically thick gas. Molecular gas in the inner part of the Galaxy tends to exhibit a higher value of  $R_{2-1/1-0}$  than in the solar neighborhood.

Accepted by ApJS

## **Disk Dissipation in Single and Binary Young Star Systems in Taurus**

**M. Simon and Lisa Prato**

Astronomy Program, State Univ. of New York, Stony Brook, NY 11794-2100, USA

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

We compare the time scales for dissipation of circumstellar disks radiating in the thermal IR in single and binary star systems in the Taurus star forming region. We accomplish this using data from the multiplicity surveys, available and new 10  $\mu\text{m}$  photometry of the unresolved systems, and the approach of Simon *et al.* (1993) to estimate the ages of the singles and the brighter member of the binaries. We find a very wide range of survival times of such disks ( $< 2 \times 10^4$  to  $10^7$  y) with no statistically significant difference between the singles and the binaries for the range of separations considered here. The time scale for the transition from an optically thick to thin disk in the thermal IR is very short ( $< 10^5$  y).

Accepted by Ap. J.

## **Beat Frequency Modulation of T Tauri Accretion Rates**

**Kester W. Smith, Ian A. Bonnell & Geraint F. Lewis**

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

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

A general model of magnetically controlled accretion onto T Tauri stars is presented. In this model the magnetic field is oriented arbitrarily in relation to the star's rotation axis. The resultant interplay between the magnetic field and accretion disc causes a variable accretion rate. The dominant timescale of this variability is the beat frequency between the stellar rotation frequency and the orbital frequency at the magnetosphere boundary. This model is analogous to that developed to explain quasi-periodic oscillations in low-mass X-ray binaries.

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## The discovery of a jetlike feature from the massive star Herschel 36

B. Stecklum<sup>1</sup>, T. Henning<sup>1</sup>, A. Eckart<sup>2</sup>, R.R. Howell<sup>3</sup>, and M.G. Hoare<sup>4</sup>

<sup>1</sup> MPG Arbeitsgruppe “Staub in Sternentstehungsgebieten”, Schillergäßchen 3, D-07745 Jena, Germany <sup>2</sup> Max-Planck-Institut für Extraterrestrische Physik, Gießenbachstr. 1, D-85748 Garching, Germany <sup>3</sup> Department of Physics and Astronomy, University of Wyoming, Laramie, WY 82071, U.S.A. <sup>4</sup> Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: pbs@physik.uni-jena.de

The O7 V star Herschel 36 has been studied in the near-infrared by ground-based high-resolution techniques. These observations and image restoration of HST-PC H $\alpha$  and [SII] images led to the detection of a jetlike feature. The interpretation of that feature being a jet is discussed in relation to a circumstellar disk for which evidence exists.

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## The companion of Z Canis Majoris detected in the visible

E. Thiébaud<sup>1</sup>, J. Bouvier<sup>2</sup>, A. Blazit<sup>3</sup>, D. Bonneau<sup>3</sup>, F.-C. Foy<sup>1</sup> and R. Foy<sup>1</sup>

<sup>1</sup> Centre de Recherche Astronomique de Lyon, CNRS UMR 142, France

<sup>2</sup> Observatoire de Grenoble, CNRS URA 708, France

<sup>3</sup> Observatoire de la Côte d’Azur, Département A. Fresnel, CNRS URA 1361, France

E-mail contact: thiebaut@image.univ-lyon1.fr

We report the detection in the visible of the companion of the FU Orionis star Z Canis Majoris discovered in the infrared by Koresko et al. (1991, AJ **102**, 6). At 730 nm and 656 nm, the companion of Z CMA appears to be much brighter than predicted by the model of Koresko et al. (1991, AJ **102**, 6). We argue that the excess flux in the visible is due to scattered light from the companion. This interpretation agrees with the results of the spectropolarimetric study of the Z CMA system by Whitney et al. (1993, ApJ **417**, 687).

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## Exploring the engines of molecular outflows. Radio continuum and H<sub>2</sub>O maser observations

Gianni Tofani<sup>1</sup>, Marcello Felli<sup>1</sup>, Gregory B. Taylor<sup>2</sup> and Todd R. Hunter<sup>2</sup>

<sup>1</sup> Arcetri Astrophysical Observatory, Largo E. Fermi 5, 50125 Firenze, Italy

<sup>2</sup> California Institute of Technology, Radio Astronomy, 105-24, Pasadena, CA 91125, U.S.A.

E-mail contact: mfeld@arcetri.astro.it

We present A-configuration VLA observations of the 22 GHz H<sub>2</sub>O maser line and 8.4 GHz continuum emission of 22 selected CO bipolar outflows associated with water masers. These observations allow us to study the region within 10<sup>4</sup> AU of the engine powering the outflow.

The positions of the maser spots are compared with those of ultra-compact (UC) continuum sources found in our observations, with IRAS data and with data from the literature on the molecular outflows. Weak unresolved continuum sources are found in several cases associated with the maser. Most probably they represent the ionized envelope surrounding the young stellar object (YSO) which powers the maser and the outflow. These weak radio continuum sources are not necessarily associated with the IRAS sources, which are more representative of the global emission from the star forming region.

A comparison of the velocity pattern of the CO outflow with those of the maser spots detected with the VLA is also made. Asymmetries in the H<sub>2</sub>O velocities are found on opposite sides of the YSO, suggesting that the outflow acceleration begins from the YSO itself. In a few cases we find evidence for two outflows in different evolutionary stages. The H<sub>2</sub>O masers in these sources are always found at the centre of the younger outflow.

The degree of variability of each maser is derived from single dish observations obtained with the Medicina radiotelescope before and after the VLA observations. Velocity drifts of some features are interpreted as acceleration the maser.

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## A Search for T Tauri Stars based on the IRAS Point Source Catalog. II.

C.A.O. Torres<sup>1</sup>, G. Quast<sup>1</sup>, R. de la Reza<sup>2</sup>, J.Gregorio-Hetem<sup>3</sup>, J.R.D. Lépine<sup>3</sup>

<sup>1</sup> Laboratório Nacional de Astrofísica/CNPq/SCT, Itajubá, MG, Brazil

<sup>2</sup> Observatório Nacional/CNPq/SCT, Rio de Janeiro, RJ, Brazil

<sup>3</sup> Instituto Astronômico e Geofísico/USP, São Paulo, SP, Brazil

E-mail contact: lepine@iagusp.ansp.br

We present the results of the continuation of a survey for new T Tauri stars, of which the first part was published by Gregorio Hetem et al.(1992). We performed spectroscopic and photometric observations of 52 candidates selected in the IRAS Point Source Catalog. We found 3 probable post-fuori stars, 17 new or probable T Tauri stars, and 13 probable Herbig Ae/Be stars.

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## The Activity of Weak-lined T Tauri Stars I: V410 Tauri

Alan D. Welty<sup>1</sup>, Lawrence W. Ramsey<sup>1</sup>

<sup>1</sup> The Pennsylvania State University, Department of Astronomy and Astrophysics,  
525 Davey Laboratory, University Park, PA 16802, USA

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

From two intensive series of spectra we have studied the phenomenology of magnetic activity and its distribution on and around V410 Tau. Large amplitude, quasi-sinusoidal radial velocity variations at the stellar rotation period appear to be due to large scale photospheric temperature inhomogeneity that has been present at least since 1988, and not to orbital motion. Other radial velocity variations imply more localized spot groups. The radial velocity variations highlight the point that radial velocity searches for brown dwarfs and planets orbiting cool stars *must* take stellar activity into account. The activity-related radial velocity variations seen in V410 Tau are *thousands* of times larger than expected radial velocity reflex motion of low-mass stars due to planets. Variations of absorption line widths are consistent with surface temperature inhomogeneities implied by the radial velocity variations. The implied temperature distribution is in qualitative agreement with Doppler images made from one of our series of spectra. We found that the cooler regions of the photosphere were associated with greater Balmer emission during the first observing run, but about 90 degrees out of phase thirteen months later. The level of Balmer emission increased from one season to the next, and flares were observed only during the latter season, suggesting an activity cycle. The net Balmer emission apparently has two strong contributors: a global chromospheric component and a variable asymmetric “halo.” Prominence-like structures appear not to be a large contributor to the non-photospheric Balmer features. Transient absorption features probably are due to infall of previously ejected material.

Accepted by Astron. J.

## *Meetings*

### FIRST ANNOUNCEMENT

First NAIC Meeting on

## MOLECULAR SPECTROSCOPY IN THE 1 TO 10 GHZ RANGE WITH THE UPGRADED ARECIBO TELESCOPE

October 18 - 20, 1995  
Arecibo, Puerto Rico

**Aim:** This is the first announcement for the Arecibo Observatory (AO) meeting on the scientific opportunities, in the field of Molecular Spectroscopy, offered to the astronomical community by the upgraded Arecibo Radiotelescope. The Upgrade Project is expected to be completed in the second half of 1996. Our aim is to bring together both old and new potential users of the telescope, to discuss what contribution the new AO is expected to give to the field.

**Topics:** The topic of the Meeting will be molecular line observations toward galactic and extragalactic objects from Arecibo, in the range 1 to 10 Ghz. In particular, we are planning to cover the following topics, *always focussed* to what will be able to be really done at AO:

- Spectral line surveys
- Molecular cloud cores
- Circumstellar material
- Maser research
- Molecular lines observations at high redshift
- Probing physical conditions with low energy transitions
- ISM studies from Arecibo

**Format:** The conference will last three days, wednesday, October 18<sup>th</sup>, thru friday, October 20<sup>th</sup>, with a Conference Banquet on friday night. It is expected to be held right before the visits of the “Arecibo Users and Scientific Advisory Committee” and the “NAIC Visiting Committee”, whose starting date is October 23<sup>rd</sup>.

It will consist of invited review talks of 1 hour duration (45 minutes plus 15 minutes for discussion), which will give a broad and thorough overview of the topics of the meeting. At present, people who have been invited and accepted to come (unless unpredictable circumstances preventing them from coming) are:

*Carl Heiles   Loris Magnani   Karl Menten   Barry Turner   Malcolm Walmsley   Alwyn Wootten*

Contributions from participants will be in the form of either *short* (10 + 5 minutes) or *long* (20 + 10 minutes) talks. Local staff may present additional talks. Given the limited room available on site for the workshop, the number of outside participants will be limited to a **maximum of 35 people**. They will be selected according to the scientific impact and relevance of their talks on the topics of the conference.

**Local Organizing Committee (further Information and Selection):** (In alphabetical order):

Daniel R. Altschuler (daniel@naic.edu)

Willem A. Baan (willem@naic.edu)

Paul F. Goldsmith (goldsmi@astrosun.tn.cornell.edu)

Luca Olmi (olmi@naic.edu)

Cornell University, NAIC,  
Arecibo Observatory,  
P.O. Box 995, Arecibo,  
PR 00613  
Tel. (809) 878-2612  
Fax (809) 878-1861