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Abstracts of recently accepted papers

Pleiades low-mass binaries: do companions affect the evolution of protoplanetary disks?

J. Bouvier[1,2], F. Rigaut[2], and D. Nadeau[3]

[1] Laboratoire d'Astrophysique, Observatoire de Grenoble, Université Joseph Fourier, B.P. 53, 38041 Grenoble Cedex 9
[2] Canada-France-Hawaii Telescope Corporation, P.O. Box 1597, Kamuela, HI 96743, USA
[3] Observatoire du Mont Mégantic et Département de Physique, Université de Montréal, C.P. 6128, Succ. A, Montréal, QC, Canada H3C 3J7
E-mail contact: bouvier@cfht.hawaii.edu

We have observed 144 G and K dwarf members of the Pleiades cluster to search for close multiple systems using CFHT's Adaptive Optics adaptor in the near-IR. We detected 22 binary systems and 3 triples, with a separation between 0.08 and 6.9 arcsec (11–910 AU). After correction for incompleteness, we derive a binary frequency in the orbital period range from 4.2 to 7.1 log days, of 28 ± 4% for G and K Pleiades dwarfs, similar to that of field G-type dwarfs (27%). The distributions of both orbital periods and mass-ratios of the Pleiades systems also appear similar to those of G dwarf binaries of the field. The binary frequency in the 100 Myr-old Pleiades cluster is much lower than that observed for Myr-old pre-main sequence (PMS) stars in the Taurus-Auriga cloud. We argue that this difference does *not* result from the evolution of the binary systems during the pre-main sequence. Instead, we suggest that the low Pleiades binary frequency is typical of stellar populations formed in dense protoclusters, while the higher binary frequency observed among Tau-Aur PMS stars is more typical of loose T associations. The implication is that most field stars are born in dense protostellar clusters.

All 144 surveyed stars have known rotational velocities. Based on the current beliefs that i) the rotation rate of Pleiades late-type dwarfs is largely dictated by the lifetime of their pre-main sequence circumstellar disks and that ii) the evolution of the disks is affected by the presence of a close companion, we searched for a relationship between rotational velocity and binarity among Pleiades G and K dwarfs. We find no significant difference between the distribution of rotational velocities of single and binary stars. Unless current models of PMS angular momentum evolution are flawed, this indicates that the presence of a companion within a distance of 10-1000 AU does not prevent accretion from occurring onto the primary at a rate similar to that observed for single PMS stars. For the closest systems, this implies that accretion must proceed from the *circumbinary* disk onto the central stars. For slightly wider systems, it suggests that the truncated circumstellar disks of the primary and of the secondary are fed by an external (circumbinary) reservoir of mass.

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Preprints are available on the WWW at: http://www.cfht.hawaii.edu/∼bouvier/bouvier.html

Protostellar fragmentation in a power-law density distribution

Andreas Burkert[1], Matthew R. Bate[1], and Peter Bodenheimer[2]

[1] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[2] UCO/Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, CA 95064, USA

Hydrodynamical calculations in three space dimensions of the collapse of an isothermal, rotating 1 $M_\odot$ protostellar cloud are presented. The initial density stratification is a power law with density $\rho \propto r^{-p}$, with $p = 1$. The case of the singular isothermal sphere ($p = 2$) is not considered; however $p = 1$ has been shown observationally to be a good

representation of the density distribution in molecular cloud cores just before the beginning of collapse. The collapse is studied with two independent numerical methods, an SPH code with 200,000 particles, and a finite-difference code with nested grids which give high spatial resolution in the inner regions. Although previous numerical studies have indicated that such a power-law distribution would not result in fragmentation into a binary system, both codes show, in contrast, that multiple fragmentation does occur in the central regions of the protostar. Thus the process of binary formation by fragmentation is shown to be consistent with the fact that a large fraction of young stars are observed to be in binary or multiple systems.

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Grain-grain collisions and sputtering in oblique C-type shocks

P. Caselli[1,2], T.W. Hartquist[2], and O. Havnes[3]

[1] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
[2] Max-Planck-Institut für extraterrestrische Physik, D-85740 Garching, Germany
[3] Auroral Observatory, University of Tromsø, N-9037 Tromsø, Norway

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

We use a model of the dissipation regions in C-type shocks in which two grain fluids are included to evaluate the rates at which grain-grain collisions and sputtering inject elemental silicon and water into the gas phase. For physical parameters typical of star forming regions, and on the assumption that a substantial fraction of the evaporated silicon is efficiently converted in SiO, the two grain destruction mechanisms lead to gas phase SiO abundances larger than those in the quiescent gas by more than three orders of magnitude. This result is in good agreement with recent observations of SiO near stellar jets. Grain-grain collisions will dominate the return of elemental silicon to the gas phase when the hydrogen nuclei number density of the region into which the shock is propagating is $n_{\rm Ho} \geq 5 \times 10^5$ $\rm cm^{-3}$ and the shock speed is between about 25 km $\rm s^{-1}$ and 35 km $\rm s^{-1}$. Grain-grain collisions dominate over sputtering in the return of water to the gas phase when $n_{\rm Ho} \geq 10^6$ $\rm cm^{-3}$ and at some shock speeds below about 15 km $\rm s^{-1}$.

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Periodic X-ray Emission from the O7 V Star θ^1 Orionis C

Marc Gagné[1], Jean-Pierre Caillault[2], John R. Stauffer[3], and Jeffrey L. Linsky[1]

[1] JILA, University of Colorado, Boulder, CO 80309-0440, USA
[2] Department of Physics and Astronomy, University of Georgia, Athens, GA 30602, USA
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: marc@colorado.edu

We report the discovery of large-amplitude, periodic X-ray emission from the O7 V star θ^1 Orionis C, the central star of the Orion Nebula. Ten *ROSAT* HRI snapshots of the Trapezium cluster taken over the course of 21 days show that the count rate of θ^1 Ori C varies from 0.26 to 0.41 counts $\rm s^{-1}$ with a clear 15-day period. The soft X-ray variations have the same phase and period as Hα and He II λ4686 variations reported by Stahl et al., and are in anti-phase with the C IV and Si IV ultraviolet absorption features. We consider five mechanisms which might explain the amplitude, phase, and periodicity of the X-ray variations: (1) colliding-wind emission with an unseen binary companion, (2) coronal emission from an unseen late-type pre-main–sequence star, (3) periodic density fluctuations, (4) absorption of magnetospheric X-rays in a corotating wind, and (5) magnetosphere eclipses. The *ROSAT* data rule out the first three scenarios, but cannot rule out either of the latter two which require the presence of an extended magnetosphere, consistent with the suggestion of Stahl et al. that θ^1 Ori C is an oblique magnetic rotator. As such, θ^1 Ori C may be the best example of a high-mass analog to the chemically peculiar, magnetic Bp stars.

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URL: `http://casa.colorado.edu/~marc/theta_letter.html`

High resolution imaging and spectroscopy of the Serpens Reflection nebula. Evidence of a latitude-dependent wind

Ana I. Gómez de Castro

Dept. de Astronomía y Geodesia, Facultad de CC. Matemáticas, Universidad Complutense de Madrid, 28040 Madrid, Spain

E-mail contact: aig@eucmos.sim.ucm.es

An optical study (high resolution images and long-slit spectra in the Hα range) of the Serpens reflection nebula (SRN) is presented. The SRN is a bipolar nebula illuminated by the low mass pre-main-sequence (PMS) star Serpens/SVS 2. The Hα profile of Serpens/SVS 2 is shown to be very broad (the width at a 10% of the peak intensity is 13.1 Å($\sim$ 600 km/s). The profile has three emission peaks centered at -137, 5 and 100 km/s. The relative strength of the peaks varies with the slit orientation. The blue and redshifted components have similar intensities at low inclinations (V5 and III0) while at high inclinations the blueshifted component is weaker than the redshifted suggesting a significant contribution of absorption by low latitude outflowing gas. These profiles could be produced in a rotating, latitude dependent wind with the outflow axis parallel to the disk axis.

The nebular Hα profile is *double* peaked; it has a blue and a redshifted component at the same velocities as the star. The profile shows no significant variations along a given PA; the emission is best explained by single scattering of the stellar radiation. The absence of the 0-velocity emission component is suggestive of the presence of warm absorbing gas within a few stellar radii. There are several knots of gas and dust embedded within the north-western (NW) nebular lobe. These knots are connected by a faint emission, defining a helical path around the major axis of the nebula. This area is also characterized by an unusually large polarization that reaches a 30-40 % at 0.95 micron that is consistent with a concentration of large and reflecting dust grains that are presumably ice coated carbon grains. This region coincides with a ridge of hot (T $\simeq$ 35 K) dust detected by IRAS along the major axis of the SRN.

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Submillimetre polarimetry of Class 0 protostars: constraints on magnetized outflow models

J.S. Greaves[1], W.S.Holland[1] and D. Ward-Thompson[2]

[1] Joint Astronomy Centre, 660 N. A'ohoku Place, University Park, Hilo, HI 96720, USA
[2] Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK

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

Polarized 800 μm emission from magnetically aligned dust grains has been detected in five protostars. Previously, only two such detections had been made. All of these protostellar sources have associated bipolar outflows, and presumably also circumstellar disks. We find that the angle between the deduced magnetic field direction and the outflow axis, $\Delta\theta$, appears to be correlated with the angle between the line-of-sight to the observer and the outflow direction, θ_{los}. If the outflow is in the plane of the sky the deduced magnetic field tends to be perpendicular to the outflow, and if the outflow is angled towards the observer, the magnetic field tends to lie parallel to the outflow. Various magnetic field geometries could explain this trend. In addition, the 800 μm percentage polarization, p, appears inversely correlated with the ratio of $L_{bol}/L_{1.3\mathrm{mm}}$, which is a measure of the source's evolutionary stage, and with bipolar outflow opening angle, which also increases as a source evolves; and correlated with source distance. We interpret these results as indicating that the observed magnetic field is more ordered in younger sources. The most likely interpretation of the distance correlation appears to be that the field is more ordered in more massive sources. As yet, there are no theoretical models for the magnetic fields around protostars which can fully explain all of these correlations.

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Optical emission line profiles of the LV knots (proplyds) in Orion

W. J. Henney[1], J. Meaburn[2], A. C. Raga[1] and R. Massey[2]

[1] Instituto de Astronomía, UNAM, Apartado Postal 70–264, 04510 México D.F., México
[2] Department of Physics and Astronomy, The University, Manchester M13 9PL, UK
E-mail contact: `will@astrosmo.unam.mx`

Compact emission line "LV knots" discovered by Laques and Vidal (1979) in the Orion Nebula (M 42) are found to spatially coincide with some of the "proplyds" discovered by O'Dell, Wen and Hu (1993) in their HST images. We therefore attempt to reproduce the line profiles observed for the LV knots with the photoevaporated disk/wind interaction model that has been developed by Henney et al. (1996) for modelling the proplyds.

In particular, we present high resolution [O III] 5007Å line profiles of the knots LV 1 (OW 168–326E), LV 2 (OW 167–317), LV 3 (OW 163–317) and LV 5 (OW 158–323), and also of another faint emission line knot (OW 171–334) in the vicinity of θ^1 Ori C. Good agreement between the theoretical predictions and the observed line profiles is found for three of the knots, in which most of the main features of the line profiles are reproduced by the model. A partial, qualitative agreement is also found for the other knots.

¿From these results we conclude that the model of a photoevaporated disk wind interacting with the wind from θ^1 Ori C at least partially succeeds in reproducing the line profiles of the proplyds associated with the LV knots.

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Time-dependent accretion and ejection implied by pre-stellar density profiles

R. Henriksen[1,2], P. André[1] and S. Bontemps[1,3]

[1] CEA, DSM, DAPNIA, Service d'Astrophysique, C.E. Saclay, F-91191 Gif-sur-Yvette Cedex, France
[2] Department of Physics, Queen's University at Kingston, Ontario, Canada
[3] Stockholm Observatory, S-133 36 Saltsjöbaden, Sweden
E-mail contact: andre@sapvxg.saclay.cea.fr

A recent homogeneous study of outflow activity in low-mass embedded young stellar objects (YSOs) (Bontemps et al. 1996) suggests that mass ejection *and* mass accretion both decline significantly with time during protostellar evolution. In the present paper, we propose that this rapid decay of accretion/ejection activity is a direct result of the non-singular density profiles characterizing pre-collapse clouds. Submillimeter dust continuum mapping indicates that the radial profiles of pre-stellar cores flatten out near their centers, being much flatter than $\rho(r) \propto r^{-2}$ at radii less than a few thousand AU (Ward-Thompson et al. 1994). In some cases, sharp edges are observed at a finite core radius. Here we show, through Lagrangian analytical calculations, that the supersonic gravitational collapse of pre-stellar cloud cores with such centrally peaked, but flattened density profiles leads to a transitory phase of energetic accretion immediately following the formation of the central hydrostatic protostar. Physically, the collapse occurs in various stages. The first stage corresponds to the nearly isothermal, dynamical collapse of the pre-stellar flat inner region, which ends with the formation of a finite-mass stellar nucleus. This phase is essentially non-existent in the 'standard' singular model developed by Shu and co-workers. In a second stage, the remaining cloud core material accretes supersonically onto a non-zero point mass. Because of the significant infall velocity field achieved during the first collapse stage, the accretion rate is initially higher than in the Shu model. This enhanced accretion persists as long as the gravitational pull of the initial point mass remains significant. The accretion rate then quickly converges towards the characteristic value $\sim a^3/G$ (where a is the sound speed), which is also the constant rate found by Shu (1977). If the model pre-stellar core has a finite outer boundary, there is a terminal decline of the accretion rate at late times due to the finite reservoir of mass.
We suggest that the initial epoch of vigorous accretion predicted by our non-singular model coincides with Class 0 protostars, which would explain their unusually powerful jets compared to the more evolved Class I YSOs. We use a simple two-component power-law model to fit the diagrams of outflow power versus envelope mass observed by Bontemps et al. (1996), and suggest that Taurus and ρ Ophiuchi YSOs follow different accretion histories because of differing initial conditions. While the isolated Class I sources of Taurus are relatively well explained by the standard Shu model, most of the Class I objects of the ρ Oph cluster may be effectively in their terminal accretion phase.

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An evolving Radio Source in the young Star Forming Region Cepheus A

V. A. Hughes

Astronomy Group/Department of Physics, Queen's University, Kingston, Ontario K7L, Canada

E-mail contact: hughesv@qucdn.QueensU.ca

Observations of Cepheus A have been carried out since 1981, covering a period of more than 13 years. In this paper we examine in detail the data on Source 3(a), which consists of two non-thermal sources which are diverging with a relative transverse speed $\sim$ 370 km s^{-1}. Source 3(a)(i) is decreasing in flux density and is seen initially at both 1.46 GHz and 4.9 GHz, but in time the 4.9 GHz flux density falls below the noise level; Source 3(a)(ii) is increasing in flux density, but is seen only at 1.46 GHz.

An application of the theory of synchrotron radiation leads to a value for the magnetic field of 3(a)(i) of 0.2G, a total magnetic field energy of 5.5×10^{44} ergs, and an energy for the relativistic particles of $\sim 10^{36}$ ergs. If 3(a)(ii) has a similar magnetic field, then the increase in flux density could be the result of the coupling of magnetic field energy into the acceleration of low-energy relativistic particles.

The morphology of the source does not place it in any known category of radio stars, but it is probably associated with a protostar, and could be evidence for a jet, or the expulsion of part of the star's magnetic field.

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Self-similarity and scaling behavior of IR emission from radiatively heated dust: I. Theory

Željko Ivezić and Moshe Elitzur

Department of Physics and Astronomy, University of Kentucky, Lexington, KY 40506-0055, USA

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

Dust infrared emission possesses scaling properties that yield powerful results with far reaching observational consequences. Scaling was first noticed by Rowan-Robinson for spherical shells and is shown here to be a general property of dust emission in arbitrary geometries. Overall luminosity is never an input parameter of the radiative transfer problem, spectral shape is the only relevant property of the heating radiation when the inner boundary of the dusty region is controlled by dust sublimation. Similarly, the absolute scales of densities and distances are irrelevant; the geometry enters only through angles, relative thicknesses and aspect ratios, and the actual magnitudes of densities and distances enter only through one independent parameter, the overall optical depth. That is, as long as the overall optical depth stays the same, the system dimensions can be scaled up or down by an arbitrary factor without any effect on the radiative transfer problem. Dust properties enter only through dimensionless, normalized distributions that describe the spatial variation of density and the wavelength dependence of scattering and absorption efficiencies.

Scaling enables a systematic approach to modeling and classification of IR spectra. We develop a new, fully scale-free method for solving radiative transfer, present exact numerical results, and derive approximate analytical solutions for spherical geometry, covering the entire range of parameter space relevant to observations. For a given type of grains, the spectral energy distribution (SED) is primarily controlled by the profile of the spatial dust distribution and the optical depth — each density profile produces a family of solutions, with position within the family determined by optical depth. From the model SEDs presented here, the density distribution and optical depth can be observationally determined for various sources.

Scaling implies tight correlations among the SEDs of various members of the same class of sources such as young stellar objects, late-type stars, etc. In particular, all members of the same class occupy common, well defined regions in color-color diagrams. The observational data corroborate the existence of these correlations.

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Non-LTE radiative transfer in clumpy molecular clouds

Mika Juvela

Helsinki University Observatory, Tähtitorninmäki, P.O.Box 14, SF-00014 University of Helsinki, Finland

E-mail contact: Mika.Juvela@helsinki.fi

We present some results of the simulation of radiative transfer in clumpy molecular clouds. For this study we have developed a program that can be used to calculate the observed molecular line profiles with one–, two– and three-dimensional model clouds. The three-dimensional models enable us to study the effect of small-scale density fluctuations on the observed molecular emission lines. The density distributions can be generated by using either fractal models or structure tree statistics.

We have made some modifications to the traditional Monte Carlo simulation scheme. These changes can in some cases significantly speed up the simulation and e.g. enable efficient calculations of clouds with high optical depths. We shall describe the principles of the implemented algorithms and present some CS spectra calculated using different clumpy cloud models.

The model calculations have confirmed that clumpy cloud structure combined with macroturbulent motions can decisively reduce self-absorption seen in molecular lines. Such effects indicate that the estimation of e.g. the column density is very uncertain without detailed knowledge of the density structure of the cloud.

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Ionization structure of the shells surrounding Herbig Ae/Be stars

A.F. Kholtygin[1], V.B. Il'in[1,2] and N.V. Voshchinnikov[1]

[1] Astronomical Institute, St. Petersburg University, St. Petersburg, 198904 Russia
[2] Max Planck Society, Research Unit "Dust in Star-Forming Regions", Schillergäßchen 3, D-07745 Jena, Germany

E-mail contact: nvv@aispbu.spb.su

The ionization balance of the circumstellar gas around Herbig Ae/Be stars is studied. The model used is based on the results obtained by Catala & Kunasz (1987) for the wind formation region of the typical Herbig Ae/Be star AB Aur. Large brightness variations of some stars are assumed to be due to their obscuration by clumps in the shells, and the gas ionization in the clumps is also considered.

It is shown that the source of ionization of gas is the radiation of the stellar photosphere and chromosphere, and the main processes that determine the ionization structure of the shells are photoionization, photorecombination and dielectronic recombination. The column density of Na I and Ca II, the central optical thickness and the equivalent width of the circumstellar Ca II K and Na I D_2 absorption lines are estimated and their dependence on the model parameters is examined. It is found that the clumps are the places where sufficiently strong variable lines may originate. The equivalent width of the lines are mainly determined by the gas to dust ratio and the element depletion in the clumps. The lines could be observed with the current large telescopes and give information on the nature of the clumps being probably the places of planet formation. The model is used to interpret two episodes of the spectral line variations observed for AB Aur and HR 5999.

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Near-infrared Spectropolarimetry of T Tauri

N. Kobayashi[1,3], T. Nagata[2], M. Tamura[1],T. Takeuchi[1], H. Takami[1], and S. Sato[2]

[1] National Astronomical Observatory, Osawa 2-21-1, Mitaka, Tokyo 181, Japan.
[2] Department of Astrophysics, Nagoya University, Chikusa-ku, Nagoya 464, Japan.
[3] Present address: Institute for Astronomy, 2680 Woodlawn Dr., Honolulu, Hawaii 96822, USA

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

We present near-infrared spectropolarimetric data between 0.9 and 4.2 μm for T Tauri. They clearly show two polarization components; one has a position angle of $\sim$90° at wavelengths shortward of $\sim$1.6 μm, the other has a position angle of $\sim$20° at wavelengths longward of $\sim$1.6 μm. The degree of polarization of the former component decreases

as the wavelength increases, while it is the reverse for the latter component. Because the polarization position angle rotates gradually from 1.4 to 1.8 μm, the rotation is likely to be explained by a combination of several scattering components and/or dichroic extinction.

In addition, an enhancement of the polarization of the longer wavelength component was clearly observed in 1990 January, when the infrared companion T Tau S was in the outburst phase (Ghez et al. 1991). The polarization increased to about three times that of the quiescent phase at 1.4−2.4 μm. The *enhancement* of the polarization in the brighter phase of T Tau S means that T Tau S is a highly polarized source. We estimated the polarization of T Tau S in the K band (2.2 μm) is 5.7 $\pm$ 1.3 %, assuming that it had been constant both in the quiescent and the outburst phase. This high polarization suggests that the polarization originates from scattering; the scattering nebulosity is compact and in the vicinity of Tau S. In view of the high polarization resulting from the scattering, we suggest that the infrared companion T Tau S is an embedded protostellar object.

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HST WFPC2 Observations of Emission Nebulosity Around XZ Tau

John E. Krist[1], Christopher J. Burrows[1], Karl R. Stapelfeldt[2], Gilda E. Ballester[3], John T. Clarke[3], David Crisp[2], John S. Gallagher III[4], Richard E. Griffiths[5], J. Jeff Hester[6], John G. Hoessel[4], Jon A. Holtzman[7], Jeremy R. Mould[8], Paul A. Scowen[7], John T. Trauger[2], Alan M. Watson[7], and James A. Westphal[9]

[1] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore MD 21218, USA

[2] Mail Stop 183-900 Jet Propulsion Laboratory, 4800 Oak Grove Drive Padadena CA 91109, USA

[3] Dept. of Atmospheric, Oceanic, and Space Sciences, Univ. of Michigan, 2455 Hayward, Ann Arbor MI 48109, USA

[4] Dept. of Astronomy, University of Wisconsin, 475 N. Charter St., Madison WI 53706, USA

[5] Dept. of Physics, Carnegie-Mellon University, Wean Hall 8311, 5000 Forbes Ave., Pittsburgh, PA 15213-3890, USA

[6] Dept. of Physics and Astronomy, Arizona State University, Tyler Mall, Tempe AZ 85287, USA

[7] Dept. of Astronomy New Mexico State University, Box 30001 Dept. 4500 Las Cruces NM 88003-8001, USA

[8] Mt. Stromlo and Siding Springs Observatories, Australian National University, Weston Creek Post Office, ACT 2611 Australia

[9] Division of Geological and Planetary Sciences, Mail Stop 170-25 Caltech, Pasadena CA 91125, USA

E-mail contact: krist@stsci.edu

XZ Tauri is a M3V T Tauri star with a pre-main sequence binary companion detected by infrared speckle interferometry at a projected separation of 0.3″ (about 40 AU). Previous ground based observations of the system have shown bipolar emission nebulosity, including a possible jet knot. Images obtained with the Wide Field and Planetary Camera 2 on the Hubble Space Telescope show an elongated, filled bubble of emission nebulosity extending over 4″ to the north of the system which contains two or three compact knots. The source of the nebulosity is undetermined. For the first time, the components are separated in visible light, and the southern component (XZ Tau S) dominates the integrated light of the system. The reverse has been found to be true in the near-infrared. Thus we confirm that XZ Tauri belongs to the small class of young binaries with cool infrared companions.

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Cometary Globules III : Triggered Star Formation in IC1848

Bertrand Lefloch[1,2], Bernard Lazareff[3] and Alain Castets[2]

[1] IRAM, Avda Divina Pastora 7, 18012 Granada, Spain

[2] Laboratoire d'Astrophysique, Observatoire de Grenoble, UJF, BP 53X, F-38041 Grenoble, France

[3] IRAM, 300 rue de la piscine, 38406 St Martin d'Hères Cedex, France

E-mail contact: lefloch@gra-ux1.iram.es

We present a multiwavelength study from molecular and continuum observations of the cometary globule CG5 in the HII region IC1848. CG5 is associated with the luminous IRAS point source 02252+6120 (L= 1100 $L_{\odot}$) and shows evidence for an energetic outflow and ongoing star formation (a cluster of low-mass stars has formed inside the cloud).

CG5 is presently undergoing a second episode of photo-ionisation from a cluster of O stars in the nebula, characterised by a shock at the surface of the cloud; the shock was detected in several millimeter lines (CO, CS) and in the thermal continuum dust emission. Photo-ionisation conditions at the surface of the globule were estimated from measurements of the VLA free-free continuum emission. From a molecular gas analysis we conclude that CG5 is permeated by a static magnetic field of strength $\approx 125\,\mu$G and is subject to an outer pressure 4 times as large as its inner pressure. It is in a globally magnetically subcritical state whereas its core is close to virial equilibrium. Photo-ionisation is found to play a key role in the evolution of CG5 because a) it confines the molecular gas and contains the gas dispersal favored by the energy injection from the outflow while evaporating the superficial layers at the same time , b) the overpressure of the compressed gas ahead of the ionisation front is sufficient to trigger the collapse of initially (sub)critical condensations inside the cloud and initiate star formation. We find that the outflow contains enough momentum to have contributed to this star-formation process. In addition, the energy of the outflow is sufficient to sustain turbulence in the cloud and maintain it in a magnetically subcritical state, i.e. it tends to stabilize the cloud against collapse and regulate star formation.

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Herbig-Haro Objects, Cometary Nebulae and PMS-stars in the NGC 7129 Star Formation Region

T. Yu. Magakian and T. A. Movsessian

Byurakan Astrophysical Observatory, National Academy of Sciences, 378433 Aragatsotn reg., Armenia

E-mail contact: tigmag@sci.am

The PMS-activity manifestations in the NGC7129 star formation region are studied on the base of the new observations and literature data. The spectrum of HH105, obtained for the first time, confirms that this is the HH object of rather low excitation and with small radial velocity. The inner structure of GGD35 is studied; in particular, the splitting of emission lines near the NE, trailing edge of the object, was found. The radial velocities field in the GGD34 knots is analysed, its sinusoidal character is confirmed. Other HH objects are shortly discussed. All reflection and cometary nebulae in the NGC7129 group are described. All presently known T Tau stars in this region are listed, for several of them the profiles of Hα emission are described. The picture of the interactions of collimated outflows with the interstellar medium in the NGC7129 vicinities is rather complicated.

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Search for young low-mass stars in a ROSAT selected sample south of the Taurus-Auriga molecular clouds

A. Magazzù[1], E.L. Martín[2], M.F. Sterzik[3], R. Neuhäuser[3], E. Covino[4], J.M. Alcalá[3]

[1] Osservatorio Astrofisico di Catania, Città Universitaria, I-95125 Catania, Italy
[2] Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain
[3] Max-Planck-Institut für Extraterrestrische Physik, D-85740 Garching, Germany
[4] Osservatorio Astronomico di Capodimonte, Via Moiariello 16, I-80131 Napoli, Italy

E-mail contact: antonio@ct.astro.it

We present results of intermediate resolution spectroscopy of 131 optical counterparts to 115 ROSAT All-Sky Survey X-ray sources south of the Taurus-Auriga dark cloud complex. These objects have been selected as candidate young stars from a total of 1084 ROSAT sources in a ~ 300 square degree area. We identify 30 objects as low-mass PMS stars on the basis of the doublet in their spectrum, a signature of their young age. All these stars have a spectral type later than F7 and show spectral characteristics typical of weak-line and post-T Tauri stars. The presence of young objects several parsecs away from the regions of ongoing star formation is discussed in the light of the current models of T Tauri dispersal.

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Quantitative spectroscopic criteria for the classification of pre-main sequence low-mass stars

Eduardo L. Martín

Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

E-mail contact: ege@iac.es

The discovery of hundreds of X-ray emitting stars possibly associated with pre-main sequence (PMS) low-mass stars far from molecular clouds, makes it necessary to adopt quantitative spectroscopic criteria for classifying them. T Tauri stars have young ages (< 10 Myr) and low masses ($M<2M_\odot$). As a consequence, it is shown that they must verify two spectroscopic conditions: (1) spectral type in the range K0-M6, and either (2a) strong emission lines and UV-optical-NIR continuum excesses, or (2b) weak-emission lines and a photospheric Lithium absorption feature with a "minimum" equivalent width which depends on spectral type. Classical T Tauris meet criteria (1) and (2a), while weak T Tauris (WTTS) meet criteria (1) and (2b).

T Tauri stars occupy a different region in the $T_{eff} - W_{LiI}$ diagramme than the low-mass members of young open clusters. Post T Tauri stars (PTTSs) later than about K2 can be clearly identified in the same diagramme because they fill an empty region (PTT-gap), intermediate between the T Tauris and the young cluster stars. The application of the spectroscopic criteria defined in this work to the PMS stars claimed to have been discovered in recent X-ray surveys of molecular clouds is hampered by the lack of high-resolution optical spectra for most of them. On the basis of the sparse and modest-resolution data that is available, the preliminary results indicate that the majority of these stars (~60%) are not WTTSs. Only ~25% of the non-WTTS X-ray discovered stars are clearly PTTSs according to this study. The PMS status of the remaining stars is dubious. It seems unlikely that the PTTSs indentified in X-ray surveys outnumber the T Tauri stars. Far away from molecular clouds, the number of WTTSs and PTTSs appear to decrease significantly.

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The rotation period of a very low-mass star in α Persei

Eduardo L. Martín & Maria Rosa Zapatero-Osorio

Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

E-mail contact: ege@iac.es

Light curves of the very low-mass member in the α Persei open cluster, AP J0323+4853, obtained during two different observing runs in 1994 and 1995 display a starspot rotational modulation of period ~7.6 hours. With a most likely mass of 0.09 $M_\odot$, close to the substellar limit, AP J0323+4853 is the lowest mass star for which a photometric rotation period has been derived so far. We discuss the implications of our result for the understanding of rotation evolution in very low-mass stars.

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Thermal Radio Sources in Bok Globules

Miguel C. Moreira[1], João Lin Yun[1], José M. Torrelles[2], & Roberto Vázquez[2]

[1]Departamento de Física, Universidade de Lisboa, Campo Grande, Ed. C1, 1700 Lisboa, Portugal
[2]Instituto de Astrofísica de Andalucía (CSIC), C/ Sancho Panza S/N, Ap. Correos 3004, 18080 Granada, Spain

E-mail contact: miguelm@delphi.cc.fc.ul.pt

We report VLA-D 6 cm continuum observations of 10 radio sources previously detected at $\lambda = 3.6$ cm towards a sample of 7 Bok globules. All sources, with the exception of CB 34 VLA1, were detected at 6 cm. We find that the spectral indices $\alpha_{(6-3.6\ cm)}$ of the emission from these objects cover a wide range, from ≥ -3.5 to 1.4. Large negative spectral indices suggesting nonthermal emission were found for the sources CB 205 VLA1,CB 205 VLA3, and CB 230 VLA1, and we cannot conclude that these sources are embedded in the Bok globules CB 205 and CB 230. Spectral

indices $\alpha_{(6-3.6\ cm)} \geq -0.1$ are exhibited by the sources CB 34 VLA1, CB 54 VLA1, CB 108 VLA1, CB 171 VLA1, CB 205 VLA2, CB 230 VLA2, and CB 244 VLA1. Thus, the cm radio continuum emission from these sources is consistent with a thermal origin, indicating that the sources are embedded in the globules. In particular, we propose CB 108 VLA1, CB 171 VLA1, and CB 205 VLA2 to be genuine Class 0 ! protostar candidates.

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A copy of this paper is available via the World Wide Web. Connect to http://delphi.cc.fc.ul.pt/papers/vla2/

The distance to the T Tauri stars in Taurus determined from their rotational properties

Thomas Preibisch and Michael D. Smith

Astronomisches Institut der Universität Würzburg, Am Hubland, D–97074 Würzburg, Germany

E-mail contact: preib@astro.uni-wuerzburg.de

We have determined the average distance to the young stars in the Taurus star formation region through their rotational properties. While most other distance estimates to star forming regions give the distance to the associated molecular clouds, the method used here gives the distance to the stars. Our statistical method assumes that the photometric variations are due to surface starspots that co-rotate with the equatorial surface speed and the rotation axes of the stars are randomly distributed. Furthermore, we pay much attention to possible unresolved binaries. A "best fit" distance of 152 ± 10 parsecs is derived from our sample of 25 weak line T Tauri stars in Taurus. This is within the range of distances found for the molecular cloud (140 pc – 160 pc) and confirms that the T Tauri stars are embedded within.

Alternatively, the agreement of the distances to the stars and dark cloud, along with their intimate sky location, lends support to the interpretation and assumptions. This means that we find a random orientation of the rotation axes, which excludes a preferential orientation that might be caused by large scale magnetic fields in the molecular cloud. Another aspect is that our results seem to exclude strong differential rotation for the T Tauri stars.

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http://www.astro.uni-wuerzburg.de/~preib/rot_dist.html

Herbig-Haro flows and molecular outflows in the HH 56/57 region

Bo Reipurth[1], M. Olberg[2], R. Gredel[1] and R. Booth[2]

[1] European Southern Observatory, Casilla 19001, Santiago 19, Chile
[2] Onsala Space Observatory, S-439 00 Onsala, Sweden

A study at optical, infrared and mm wavelengths has been carried out of the Sa 187 cloud in the southern constellation of Norma, which harbors the HH 56 and 57 flows. CCD images of HH 56 show that it has a fine bow shock morphology. Along the line defined by HH 56 and its energy source Re 13 we have found a faint HH object, HH 56N, to the north, and another bow shock, HH 56S, to the south, making HH 56 a large (0.76 pc in projection) bipolar HH flow. Recent CCD images of HH 57 compared to earlier ones show structural variability of the reflection nebula surrounding the FU Orionis driving source V346 Nor. Infrared photometry of V346 Nor collected over a decade shows an irregular variability in J and H, and a gradual brightening in K, L and M, suggesting that the FU Orionis eruption may not yet have peaked. Sensitive high-resolution K-band spectra of V346 Nor have revealed weak emission in the first overtone bands of CO, making it the first FUor known to show CO emission. Extensive ^{12}CO, ^{13}CO and CS mm-observations are used to describe the molecular environment of the HH sources. We present detailed ^{12}CO maps of two large molecular outflows, each one centered on one of the HH sources and co-axial with their associated HH flows. The outflow lobes coincide with visible cavities, outlined against the rich background star fields, in the surrounding molecular cloud. Finally, we identify two young IRAS sources in the extended tail of the Sa 187 cloud and present a ^{12}CO map of one or two associated small molecular outflows.

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Physics of Accretion onto Young Stars. II Structure and evolution of accreting stars

Lionel Siess, Manuel Forestini and Claude Bertout

Observatoire de Grenoble, Laboratoire d'Astrophysique, Université Joseph Fourier, B.P.53X, F-38041, Grenoble Cedex 9, France

E-mail contact: siess@gag.observ-gr.fr

We present new computations of pre-main sequence evolution for stars that accrete a substantial part of their mass. We compute several models with different mass accretion rates, focusing on the effect of deuterium burning on stellar evolution during the accretion phase. We treat accretion not only as a surface boundary condition but as a global phenomenon that affect also the inner parts of the star, using a formalism developed by Siess & Forestini (1996a). We study the effect of varying the mass distribution of accreted matter into the star, and analyze the influence of different chemical compositions for the accreted matter. We also take into account the possible deposition of accretion energy transported by the accreted matter. We show that accretion can lead to substantial changes in the pre-main sequence evolutionary tracks in the Hertzsprung-Russell diagram (HRD). When accretion stops, the star relaxes to its "standard" track in the HRD, and this, independently of the previous accretion rate.

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Numerical hydrodynamic simulations of jet-driven bipolar outflows

Michael D. Smith, Gerhard Suttner & Harold W. Yorke

Astronomisches Institut der Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

E-mail contact: smith@, suttner, yorke @astro.uni-wuerzburg.de

The jet model for protostellar outflows is confronted with the constraints imposed by CO spectroscopic observations. From three dimensional simulations of a dense molecular medium being penetrated by a denser molecular jet, we simulate line profiles and construct position-velocity diagrams for the (low-J) CO transitions. We find (1) the profiles imply power law variation of integrated brightness with velocity over a wide range of velocities, (2) the velocity field resembles a 'Hubble Law' and (3) a hollow-shell structure at low velocities becomes an elongated lobe at high velocities. Moreover, the leading bow shock produces strong forward motion of the cool gas rather than the expected lateral expansion. We are thus able to satisfy the Lada and Fich (1996) criteria, employing NGC 2264G as an example.

Deviations from the simple power law dependence of integrated brightness versus velocity occur at high velocities in our simulations. The curve first dips to a shallow minimum and then rises rapidly and peaks sharply. Reanalysis of the NGC 2264G and Cepheus E data confirm these predictions. We identify these two features with a jet-ambient shear layer and the jet itself.

A deeper analysis reveals that the power-law index is an indicator of the evolutionary stage: a profile steepens with time. Also, the CO excitation temperature changes along the bow walls and thus a CO line intensity does not directly yield the mass distribution, as often assumed. Instead, the CO emission is enhanced near the excitation peaks.

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Infrared response of H_2 to X-rays in dense clouds

S. Tiné, S. Lepp[1], R. Gredel[2] and A. Dalgarno[3]

[1] Physics Dept., University of Nevada, Las Vegas, NV 89154-4002, USA

[2] European Southern Observatory, Casilla 19001, Santiago 19, Chile

[3] Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: rgredel@eso.org

The excitation by X-rays and cosmic rays of molecular hydrogen in interstellar clouds is analyzed. We carried out detailed calculations of entry efficiencies in rovibrational levels of H_2 following impact with fast electrons produced by X-ray ionization of the gas. The competing effect of collisional excitation, and quenching, by the ambient gas is examined in detail. Up to date values for H-H_2 collisional rate coefficients are adopted, and some derivations of H_2-H_2rovibrational rate coefficients from existing literature data are proposed. Several models as a function of temperature, density and ionization rate are presented. We found that H_2 infrared emission in X-ray dominated regions (XDR) is potentially observable for temperatures and ionization rates lower than certain critical values (typically T <1000K and $\zeta/n_H < 10^{-15}$ cm^{-3}, where ζ is the ionization rate). At higher temperatures, collisional excitation by the ambient gas dominates the population of low vibrational levels, and at higher values for ζ/n_H the abundance of H_2 is negligible. If such conditions are satisfied, the resulting infrared emission spectrum can be used as a diagnostic of nearby X-ray sources such as in cooling flows in galaxy clusters, quasars, Seyfert galaxies and supernova remnants. The intensity ratio of the 2-1 S(1) and 1-0 S(1) lines measured for the Seyfert galaxy NGC1275 is consistent with X-ray pumping.

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Molecular Clouds in Cepheus and Cassiopeia

Yoshinori Yonekura[1], Kazuhito Dobashi[2], Akira Mizuno[1], Hideo Ogawa[1] and Yasuo Fukui[1]

[1] Department of Astrophysics, Nagoya University, Nagoya, 464-01, Japan

[2] Space and Life Science, Osaka Prefecture University, Sakai, 593, Osaka, Japan

E-mail contact: yonekura@a.phys.nagoya-u.ac.jp

A large-scale ^{13}CO(J = 1–0) survey for nearby molecular clouds was performed toward the Cepheus and Cassiopeia regions ($100^\circ < l < 130^\circ$ and $-10^\circ < b < 20^\circ$) with the velocity coverage of $-40 < V_{\rm LSR} < +20$ km s^{-1} by using the two 4 meter millimeter telescopes at Nagoya University. An area of 866 square degrees was covered at an $8'$ grid spacing with a $2\rlap{.}'7$ beam, and 48,750 positions were observed. Significant ^{13}CO emission (≥ 1.8 K km s^{-1} = 3σ) is detected at 1,015 positions. On the basis of the ^{13}CO data, 188 distinct ^{13}CO clouds are identified whose total mass is $1.0 \times 10^5 M_\odot$. Physical properties of the ^{13}CO clouds such as molecular column densities, sizes, and masses are derived for each cloud. Astronomical objects associated with the ^{13}CO clouds were searched for in the literature: 10 HII regions, 8 reflection nebulae, 23 T Tauri type stars, 28 molecular outflows, and 125 *IRAS* point sources selected as candidates for protostars are likely to be associated with the ^{13}CO clouds.

Statistical studies on the ^{13}CO clouds detected in this survey have been made. The mass spectra of the ^{13}CO clouds in Cepheus and Cassiopeia are well represented by a power law, $dN_{\rm cloud}/dM_{\rm cloud} \propto M_{\rm cloud}^{-\alpha}$, with $\alpha = 1.7 \pm 0.3$ in a cloud mass range 10^1–$10^5 M_\odot$, which is similar to previously observed other regions like Cygnus. We also investigated the relation between the line width and the size of the ^{13}CO clouds, and found that there is no significant correlation among them in the cloud mass range 10^1–10^4 $M_\odot$. A virial analysis made for the ^{13}CO clouds indicates that the relation between the virial mass $M_{\rm vir}$ and the mass measured in ^{13}CO $M_{\rm cloud}$ is approximated well by $(M_{\rm vir}/M_\odot) = 2.8 \times 10^1 (M_{\rm cloud}/M_\odot)^{0.62}$, suggesting that smaller clouds tend to be more weakly bound than larger clouds gravitationally or are dispersing if the possible external pressure is disregarded. It is found that the ^{13}CO clouds associated with *IRAS* point sources, which are regarded as ongoing star-forming clouds, tend to be more massive and larger in size, and to have higher column densities than those without any signs of star formation. There seems to be a threshold value in the peak H_2 column density of $N(H_2) = 2.5 \times 10^{21}$cm^{-2} for stars to form in a ^{13}CO cloud.

In order to study star formation activities in the ^{13}CO clouds, we investigated the global luminosity distribution of the *IRAS* point sources, and attempted to determine the distribution as a function of the parent molecular cloud mass. The *IRAS* luminosity function in a given cloud with mass $M_{\rm cloud}$ is found to be well approximated by a power law $dn_{\rm star}/dL_{\rm star} = 6 \times 10^{-3} (M_{\rm cloud}/M_\odot)^{0.8} (L_{\rm star}/L_\odot)^{-1.5} L_\odot^{-1}$ for the *IRAS* luminosity range $1 < L_{\rm star}/L_\odot < 10^5$ and the cloud mass range $10^1 < M_{\rm cloud}/M_\odot < 10^5$. The luminosity function does not depend significantly on the cloud mass, the regions sampled, and the existence of HII regions. The luminosity of the most luminous *IRAS* point source in a given molecular cloud $L_{\rm star,max}$ increases systematically with the mass of the associated cloud, which is fitted by the power law $(L_{\rm star,max}/L_\odot) = 0.098 \times (M_{\rm cloud}/M_\odot)^{1.43}$. These relations are found to be consistent with those derived in Cygnus by Dobashi, Bernard, & Fukui (1996),suggesting that they may represent general relations between the maximum *IRAS* luminosity and the molecular clouds. We finally demonstrate that the slope of the initial mass function estimated from the *IRAS* luminosity function derived here is consistent with the stellar initial mass function for a stellar mass to luminosity relation of $(L_{\rm star}/L_\odot) = (M_{\rm star}/M_\odot)^{3.45}$.

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http://www.a.phys.nagoya-u.ac.jp/~yonekura/work/ApJScepcas/

Brown Dwarfs in the Pleiades Cluster. II. J, H and K photometry

M.R. Zapatero Osorio, E.L. Martín and R. Rebolo

Instituto de Astrofísica de Canarias, Vía Láctea s/n, E-38200 La Laguna, Tenerife, Spain

E-mail contact: mosorio@iac.es

www page: http://www.iac.es/publicaciones/preprints.html

We have obtained near-infrared observations of some of the faintest objects so far known towards the Pleiades young stellar cluster, with the purpose of investigating the sequence that connects cluster very low-mass stars with substellar objects. We find that infrared data combined with optical magnitudes are a useful tool to discriminate cluster members from foreground and background late-type field stars contaminating optical surveys. The bottom of the Pleiades sequence is clearly defined by the faint HHJ objects as the very low-mass stars approaching the substellar limit, by the transition object PPl 15, which will barely ignite its hydrogen content, and by the two brown dwarfs Calar 3 and Teide 1.

Binarity amongst cluster members could account for the large dispersion observed in the faint end of the infrared colour-magnitude diagrams. Two objects in our sample, namely HHJ 6 and PPl 15, are overluminous compared to other members, suggesting a probable binary nature. We have reproduced the photometric measurements of both of them by combining the magnitudes of cluster very low-mass stars and brown dwarfs and using the most recent theoretical evolutionary tracks. The likely masses of the components are slightly above the substellar limit for HHJ 6, while they are 0.080 and 0.045±0.010 $M_{\odot}$ for PPl 15. These masses are consistent with the constraints imposed by the published lithium observations of these Pleiads.

We find a single object infrared sequence in the Pleiades cluster connecting very low-mass stars and brown dwarfs. We propose that the substellar mass limit ($\sim$0.075 $M_{\odot}$) in the Pleiades ($\sim$120 Myr) takes place at absolute magnitudes $M_{\rm I}$ = 12.4, $M_{\rm J}$ = 10.1, $M_{\rm H}$ = 9.4 and $M_{\rm K}$ = 9.0 (spectral type M7). Cluster members fainter by 0.2 mag in the I-band and 0.1 mag in the K-band should be proper brown dwarfs. The star-brown dwarf frontier in the Hyades cluster (600 Myr) would be located at $M_{\rm I}$ = 15.0, $M_{\rm J}$ = 11.6, $M_{\rm H}$ = 10.8 and $M_{\rm K}$ = 10.4 (spectral type around M9). Fon an age older than 1000 Myr we estimate that brown dwarfs are fainter than $M_{\rm K}$ = 10.9 (spectral type later than M9.5).

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Dissertation Abstracts

Watching the Stars go 'Round and 'Round

Scott J. Wolk

Thesis work conducted at: Astronomy Program, SUNY at Stony Brook, NY, USA

Current address: Harvard–Smithsonian Center for Astrophysics Cambridge, Massachusetts, USA

Electronic mail: swolk@cfa.harvard.edu

Ph.D dissertation directed by: Frederick M. Walter

Ph.D degree awarded: December 1996

I present results from several seasons of photometric observations of X–ray sources in the Orion OB1a and OB1b star formation regions. The initial goal was to measure the rotational periods of several dozen pre–main sequence (PMS) stars. Since the early 1980s, X–rays have been found to be the premier method of identifying PMS stars, especially in highly confused regions. I first describe previous work in rotational studies, beginning with spectrophotographic observations of $v \sin i$ through the modern use of charge coupled devices to study the rotational modulation of spotted stars. The optical properties of 105 X–ray sources observed as part of my thesis research are discussed in detail next. Based on optical colors, I find that the X–ray sources in both regions lie along a well defined locus above the main sequence. Infrared and optical data confirm that 90% of the X–ray sources are PMS and about 10% of the PMS stars may have disks. Between V magnitudes 12 and 16, I find that the X–ray sources account for 80% of the pre–main sequence population, as determined by location in the H–R diagram. This photometric study also reveals a population of PMS stars to which the X–ray surveys were insensitive. These PMS stars range in mass from Solar mass objects, down to very close to the brown dwarf limit. This photometric method, augmented by spectra, may supplant X–rays as the premier method for identification of PMS sources in regions of star formation. It may also provide a method for observing stars at the low mass end of the initial mass function.

With the PMS nature of these X–ray sources well characterized, I examine the periodic nature of only the stars which were associated with X–ray sources. I use simulated data to demonstrate that for stars with perfectly sinusoidal behavior, accurate periods can be found in a cases of signal to noise greater than 2. that the For more realistic stars, which do not vary in brightness (along our line–of–sight) exactly as a sine wave, the signal to noise must be higher by a factor of two or more. I also discuss the expected color changes due to spot modulation and find that the allowed variations cover a very limited range in phase space. I find rotation periods for five stars at confidence of greater than 99.9%. Five additional rotation periods were found with confidence of greater than 99%. Rotation periods of 49 additional stars were found at much lower confidence.

Finally, the relation between the data presented here and other data is discussed. The sampling rate of the data presented here allows for detection of shorter periods than previously reported for T Tauri stars. I note the bimodal distribution of rotation periods which other authors have reported. I further note that the ratio of slow rotators to fast rotators seems to change as a function of the age of the star forming region. Rotation period and various observables are compared. I find weak correlations between slow rotation and high variability and between slow rotation and IR color excess. Both these correlations support the hypothesis that stars with disks are slow rotators. However, there is also a large fraction of slow rotators which do not show evidence for disks.

available at http://hea-www.harvard.edu/~swolk/swolk.html