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Abstracts of recently accepted papers

Herbig-Haro Flows near Compact Reflection Nebulae

Colin Aspin[1] and Bo Reipurth[2]

[1] University of Oxford, Nuclear and Astrophysics Lab, Keble Road, Oxford OX1 3RH, United Kingdom
[2] CASA, Univ. of Colorado, Boulder, CO 80309, USA

E-mail contact: caa@astro.ox.ac.uk

We have performed an optical CCD imaging survey of star forming regions identified through compact reflection nebulae and/or embedded IRAS sources in order to search for new Herbig-Haro (HH) flows. Here we present the discovery of hitherto unknown HH objects in 7 of these regions. A bright bow shock, HH 461, is found along the axis defined by the previously known HH 164 jet from the luminous young A-star LkHα 198. The little known cometary nebula PP 11, illuminated by the partly embedded IRAS source 03507+3801 in the Perseus clouds, contains an HH object, HH 462, found along the symmetry axis of the nebula. A small jet, HH 463, emanates from the recently identified FU Orionis candidate PP 13S, while another HH flow, HH 464/HH 465 appears to originate from the nearby T Tauri star PP 13N. A group of HH objects, HH 466–468, are located around the nebulous young T Tauri binary GK Tau. A well collimated HH jet and an associated bow shock, HH 470, are found extending from the young nebulous T Tauri star Haro 4-255 in Orion, and a tiny reflection nebula and associated HH object, HH 469 is located close by the deeply embedded Class I source Haro 4-255 FIR. In light of these new HH flows in Haro 4-255, we re-interpret existing ^{12}CO data on this source in terms of two overlapping molecular outflows. The young star LkHα 316 and the nearby IRAS source 05451+0037 in Orion are found to be associated with a cluster of HH objects, HH 471–474. It is likely that a nearby and previously identified HH object, HH 71, also originates in this region. Finally, a chain of HH objects, HH 475, are found near the little studied compact bipolar reflection nebula PP 95 in the Cygnus clouds. The origin of this HH chain remains unclear and HH 475 may equally well be driven by one of several luminous massive young stars in the region.

Accepted by MNRAS

Preprints are available on the web at

http://gemini.physics.ox.ac.uk
button FTP (Outgoing)
path caa/papers/HHopt
files HHopt.ps.gz HHopt-fig.ps.gz

Reprocessing in Luminous Disks

K. R. Bell

NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035, USA

E-mail contact: bell@cosmic.arc.nasa.gov

We develop and investigate a procedure that accounts for disk reprocessing of photons that originate in the disk itself. Surface temperatures and simple, black body spectral energy distributions (SEDs) of protostellar disks are calculated. In disks that flare with radius, reprocessing of stellar photons results in temperature profiles which are not power-law at all radii but are consistently shallower than $r^{-3/4}$. Including the disk as a radiation source (as in the case of active accretion) along with the stellar source further flattens the temperature profile. Disks that flare strongly near the star and then smoothly curve over and become shadowed at some distance ("decreasing curvature" disks) exhibit nearly power-law temperature profiles which result in power-law infrared SEDs with slopes in agreement with typical observations of young stellar objects. Disk models in which the photospheric thickness is controlled by the local opacity and in which the temperature decreases with radius naturally have this shape. Uniformly flaring models do not match observations as well; progressively stronger reprocessing at larger radii leads to SEDs that flatten toward the infrared or even have a second peak at the wavelength corresponding (through the Wien law) to the temperature of the outer edge of the disk.

In FU Orionis outbursting systems, the dominant source of energy is the inner disk. Reprocessing throughout the disk depends sensitively on the inner disk shape and emitted temperature profile. We show that the thermal instability outburst models of Bell & Lin reproduce trends in the observed SEDs of Fuors with $T \propto r^{-3/4}$ in the inner disk ($r \lesssim 0.25au$ corresponding to $\lambda \lesssim 10\mu$m) and $T \propto r^{-1/2}$ in the outer disk. Surface irradiation during outburst and quiescence is compared in the region of planet formation ($1-10\ au$). The contrast between the two phases is diminished by the importance of the reprocessing of photons from the relatively high mass flux, outer disk ($\dot{M} = 10^{-5}M_{\odot}yr^{-1}$) which is present during both outburst and quiescence.

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http://www-space.arc.nasa.gov/~krbell/papers/papers.html

The Jeans Condition and Collapsing Molecular Cloud Cores: Filaments or Binaries?

Alan P. Boss[1], Robert T. Fisher[2], Richard I. Klein[3], and Christopher F. McKee[4]

[1] DTM, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015-1305, USA
[2]Physics Dept., University of California, Berkeley, CA 94720, USA
[3]Dept. of Astronomy, University of California, Berkeley, and Lawrence Livermore National Laboratory, P.O. Box 808, L-23, Livermore, CA 94550, USA
[4]Physics Department, University of California, Berkeley, CA 94720, USA

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

Truelove et al (1997, 1998) introduced the Jeans condition as a necessary condition for avoiding artificial fragmentation during protostellar collapse calculations. They found that when the Jeans condition was properly satisfied with their adaptive mesh refinement (AMR) code, an isothermal cloud with an initial Gaussian density profile collapsed to form a thin filament, rather than the binary or quadruple protostar systems found in previous calculations. Using a completely different self-gravitational hydrodynamics code (Boss & Myhill 1992; B&M), we present here calculations that reproduce the filamentary solution first obtained by Truelove et al (1997). The filamentary solution only emerged with very high spatial resolution with the B&M code, with effectively 12,500 radial grid points (R_{12500}). Reproducing the filamentary collapse solution appears to be an excellent means for testing the reliability of self-gravitational hydrodynamics codes, whether grid-based or particle-based. We then show that in the more physically realistic case of an identical initial cloud with nonisothermal heating (calculated in the Eddington approximation with code B&M), thermal retardation of the collapse permits the Gaussian cloud to fragment into a binary protostar system at the same maximum density where the isothermal collapse yields a thin filament. However, the binary clumps soon thereafter evolve into a central clump surrounded by spiral arms containing two more clumps. A roughly similar evolution is obtained using the AMR code with a barotropic equation of state – formation of a transient binary, followed by decay of the binary to form a central object surrounded by spiral arms, though in this case the spiral arms do not form clumps. When the same barotropic equation of state is used with the B&M code, the agreement with the initial phases of the AMR calculation is quite good, showing that these two codes yield mutually consistent results. However, the B&M barotropic result differs significantly from the B&M Eddington result at the same maximum density, demonstrating the importance of detailed radiative transfer effects. Finally, we confirm that even in the case of isothermal collapse, an initially uniform density sphere can collapse and fragment into a binary system, in agreement with the results of Truelove et al (1998). Fragmentation of molecular cloud cores thus appears to remain as a likely explanation of the formation of binary stars, but the sensitivity of these calculations to the numerical resolution and to the thermodynamical treatment demonstrates the need for considerable caution in computing and interpreting three dimensional protostellar collapse calculations.

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Preprint at http://www.ciw.edu/ftp/boss/jeansii

Magnetospheric accretion onto the T Tauri star AA Tau
I. Constraints from multisite spectrophotometric monitoring

J. Bouvier[1], A. Chelli[1], S. Allain[1], L. Carrasco[2,3], R. Costero[3], I. Cruz-Gonzalez[3], C. Dougados[1], M. Fernández[4], E.L. Martín[5], F. Ménard[1,6], C. Mennessier[1], R. Mujica[2], E. Recillas[2], L. Salas[3], G. Schmidt[7] and R. Wichmann[8]

[1] Laboratoire d'Astrophysique, Observatoire de Grenoble, Université Joseph Fourier, B.P. 53, 38041 Grenoble Cedex 9, France
[2] Instituto Nacional de Astrofísica Optica y Electrónica, Apartado Postal 51 y 216, C.P. 72000, Puebla, Pue., México
[3] Instituto de Astronomia, UNAM, Ap. Postal 70264, 04510, México
[4] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse, D-85740 Garching, Germany
[5] Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain
[6] Canada-France-Hawaii Telescope Corp., PO Box 1597, Kamuela, HI 96743, USA
[7] Steward Observatory The University of Arizona Tucson, AZ 85721, USA
[8] Landessternwarte Königstuhl, D-69117 Heidelberg, Germany

E-mail contact: jbouvier@laog.obs.ujf-grenoble.fr

We have monitored the photometric, spectroscopic and polarimetric variations of the classical T Tauri star (CTTS) AA Tau over a period of a month. The light curve consists of more than 260 measurements in each of the B and V-bands over a continuous time period of 30 days and more than 180 measurements in the R and I-bands. This provides unprecedented detail of the photometric variations of a CTTS on timescales ranging from hours to weeks.

We find that AA Tau's light curve is quite unlike that of most other CTTS. It exhibits a roughly constant brightness level, interrupted by quasi-cyclic fading episodes with an amplitude of 1.4 mag in BVRI filters. We interpret this behaviour as resulting from quasi-periodic occultations of the stellar photosphere by opaque circumstellar material. The interpretation derives from the lack of significant color variations associated with the fading of the system and is strengthened by the higher polarization level measured when the system is faint.

We argue that the occultations are produced by a warp in AA Tau's inner disk which presumably results from the dynamical interaction between the disk and the stellar magnetosphere. We present a model that accounts for the observations quite naturally if we assume that the stellar magnetosphere is a large-scale dipole tilted onto the stellar rotational axis which disrupts the disk at the corotation radius. We derive the geometrical properties of AA Tau's accretion zone in the framework of this model and constrain the location of veiling and Balmer line emitting regions.

Although AA Tau's light curve is atypical, the constraints derived here on the structure of its accretion zone may apply as well to other CTTS. It is probably only because AA Tau is seen at a peculiar inclination, close to edge-on, that occultations are conspicuous and its photometric behaviour so clearly reveals this phenomenon.

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Preprints available at: http://www-laog.obs.ujf-grenoble.fr/activites/starform/formation.html

CO depletion in the starless cloud core L1544

P. Caselli[1], C. M. Walmsley[1], M. Tafalla[2], L. Dore[3], and P. C. Myers[4]

[1] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
[2] Observatorio Astronómico Nacional, Apartado 1143, E-28800, Alcalá de Henares (Madrid), Spain
[3] Dipartimento di Chimica "G. Ciamincian", Università di Bologna, Via Selmi 2, I-40126 Bologna, Italy
[4] Harvard–Smithsonian Center for Astrophysics, MS 42, 60 Garden Street, Cambridge, MA 02138, USA

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

We present evidence for CO depletion towards the starless cloud core L1544. A comparison between $C^{17}O$ and the 1.3 mm continuum dust emission shows that CO is depleted by a factor of ~ 10 at the dust peak. Our observations are consistent with a model where CO is condensed out onto dust grains at densities above $n_{\rm d} \sim 10^5$ cm^{-3}. The corresponding radius of the "depleted region" is $r_{\rm d} \sim 6500$ AU and we find that this depletion causes 2.3 $M_\odot$ of gas to be lost to view in molecular line emission. Optically thin high density tracers, such as $HC^{18}O^+$ and $D^{13}CO^+$, show double peaked profiles which suggest that we are observing superposed emission from the foreground and background undepleted layers with density below $n_{\rm d}$. The relative velocities between these layers is sufficiently small however that we conclude that the core is relatively young ($\sim 10^4$ years old). For the component at $V_{\rm LSR} = 7.1$ km s^{-1} in this line of sight, we estimate [DCO$^+$]/[HCO$^+$] = 0.12 ± 0.02 which is larger by a factor of order 2 than values derived in other dense cloud cores.

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The fragmentation of cold slabs: application to the formation of clusters.

C.J.Clarke

Institute of Astronomy, Madingley Road, Cambridge, CB3 OHA, U.K.

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

We investigate the evolution of self-gravitating modes in slab-like systems with zero pressure support. We find that temporary cooling of gaseous slabs does not lead to fragmentation during the time that the slab collapses to the mid-plane, a result that contrasts with that in spherical geometry. We also find that in stellar dynamical applications (where the slab executes repeated oscillations normal to its plane), it is only modes with horizontal wavelength less than or of order the slab thickness that are monotonically amplified. We discuss the application of this result to the violent relaxation of highly flattened stellar clusters.

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Composite Polytrope Models of Molecular Clouds. I. Theory

Charles L. Curry[1,2] and Christopher F. McKee[3]

[1] Astronomy Department, University of California, Berkeley, CA, U.S.A. 94720
[2] Department of Physics and Astronomy, University of Western Ontario, London, ON, Canada N6A 3K7
[3] Departments of Physics and Astronomy, University of California, Berkeley, CA, U.S.A. 94720

E-mail contact: curry@astro.uwo.ca

We construct spherical, hydrostatic models of dense molecular cores and Bok globules consisting of two distinct, spatially separate gas components: a central, isothermal region surrounded by a negative-index, polytropic envelope. The clouds are supported against their own self-gravity by a combination of thermal, mean magnetic, and turbulent wave pressure. The latter two are included by allowing for locally adiabatic, non-isentropic pressure components. Such models are meant to represent, in a schematic manner, the velocity and density structure of cores and globules, as inferred from molecular line and dust continuum observations. In addition, our picture reflects the theoretical expectation that MHD wave motions, which are important at scales $\gtrsim 0.1$ pc in typical low-mass star-forming regions, are damped at smaller scales, giving rise to a finite-sized, thermally-dominated core region. We show that if the pressure components are isentropic, then the pressure drop from the center to the edge of the composite polytropes we consider is limited to 197, the square of the value for the Bonnor-Ebert sphere. If the pressure components are non-isentropic, it is possible to have arbitrarily large pressure drops, in agreement with the results of McKee & Holliman (1999). However, we find that even for non-isentropic pressure components, the ratio of the *mean* to surface pressure in the composite polytropes we consider is less than 4. We show by explicit construction that it is possible to have dense cores comparable to the Jeans mass embedded in stable clouds of much larger mass. In a subsequent paper, we show that composite polytropes on the verge of gravitational instability can reproduce the observed velocity and density structure of cores and globules under a variety of physical conditions.

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Accretion Disks around Young Objects. II. Tests of Well-Mixed Models with ISM Dust

Paola D'Alessio[1], Nuria Calvet[2], Lee Hartmann[2], Susana Lizano[1], and Jorge Cantó[1]

[1] Instituto de Astronomía, UNAM, Ap. Postal 70-264, Cd. Universitaria, 04510 México D.F., México
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

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

We construct detailed vertical structure models of irradiated accretion disks around T Tauri stars with interstellar medium dust uniformly mixed with gas. The dependence of the structure and emission properties on mass accretion rate, viscosity parameter, and disk radius is explored using these models. The theoretical spectral energy distributions (SEDs) and images for all inclinations are compared with observations of the entire population of Classical T Tauri stars (CTTS) and Class I objects in Taurus. In particular, we find that the median near-infrared fluxes can be explained within the errors with the most recent values for the median accretion rates for CTTS. We further show that the majority of the Class I sources in Taurus cannot be Class II sources viewed edge-on because they are too luminous and their colors would be consistent with disks seen only in a narrow range of inclinations. Our models appear to be too geometrically thick at large radii, as suggested by: (a) larger far-infrared disk emission than in the typical SEDs of T Tauri stars; (b) wider dark dust lanes in the model images than in the images of HH30 and HK Tau/c; and (c) larger predicted number of stars extincted by edge-on disks than consistent with current surveys. The large thickness of the model is a consequence of the assumption that dust and gas are well-mixed, suggesting that some degree of dust settling may be required to explain the observations.

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Jets from Accreting Magnetic Young Stellar Objects – I. Comparison of Observation and High Resolution Simulation Results

Anthony P. Goodson[1], Karl-Heinz Böhm[2] and Robert M. Winglee[3]

[1] Physics Department, University of Washington, Seattle, WA 98195, USA
[2] Astronomy Department, University of Washington, Seattle, WA 98195, USA
[3] Geophysics Program, University of Washington, Seattle, WA 98195, USA

E-mail contact: anthony@geophys.washington.edu

High resolution numerical magnetohydrodynamic (MHD) simulations of a new model for the formation of jets from magnetic accreting young stellar objects (YSOs) are presented and compared with observations. The simulation results corroborate a previously laid out conceptual mechanism for forming jets, where the interaction of the stellar magnetosphere with a surrounding accretion disk leads to an outflow. The high resolution of the numerical simulation allows optical condensations which form in the region close to the star to be seen. The optical condensations and the episodic behavior of the jet are effects that are inherent to the jet launching mechanism itself. A disk wind arises as well.

The simulated outflow is compared with observations, and it is shown that simulated images in the forbidden lines [SII](6716+6731) have morphology consistent with recent observations of the jet source HH30. Furthermore, velocity spectra of the simulated outflow in [SII](6716+6731) and mass weighted by n clearly show a two component outflow in agreement with observed outflows from T-Tauri stars such as DG Tauri. The mechanism produces a highly collimated fast jet and a slower disk wind. While the match between existing observations and the simulated system are not perfect (the time and size scales of the jet differ from those in HH30 by an order of magnitude), the morphology associated with both imagery and velocity spectra of the jet are matched well. A companion paper (paper II) lays out the physics that control the time scale for knot production and defines the controlling parameters of the jet launching mechanism in general.

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Jets from Accreting Magnetic Young Stellar Objects – II. Mechanism Physics

Anthony P. Goodson[1] and Robert M. Winglee[2]

[1] Physics Department, University of Washington, Seattle, WA 98195, USA
[2] Geophysics Program, University of Washington, Seattle, WA 98195, USA

E-mail contact: anthony@geophys.washington.edu

This paper addresses the physical principles underpinning a new jet launching mechanism described in a companion paper (paper I). In this new jet formation model, magnetic loops which connect the star to the disk become twisted and expand via helicity injection. This expansion drives an outflow, with the axial symmetry of the disk leading to a concentration of outflowing plasma along the rotation axis, forming the jet. In paper I, it is found that the radial location of the inner edge of the disk undergoes oscillations. In this paper, the physical cause of the disk oscillations are investigated. This investigation leads to the conclusion that there are three classes of flows that can arise, depending on the role of diffusive instabilities. The most diffusive flows (Ghosh & Lamb 1978, 1979a, 1979b) allow the stellar magnetic field to slip through the accretion disk and yield steady accretion flows. Such configurations are unlikely to produce outflows. The flows with intermediate diffusivity have been described by Lovelace, Romanova & Bisnovatyi-Kogan (1995), and represent conditions where the field is effectively frozen into the accretion disk azimuthally, but slips radially. In the absence of magnetic reconnection, such configurations are predicted to produce steady flows with logarithmically collimated disk winds. The least diffusive flows, in which the bulk radial disk velocity is greater at times than the speed with which magnetic field lines can diffuse into the disk, lead to the formation of the collimated unsteady jets described in paper I and are the primary interest of this paper. The jet velocity is also addressed.

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He II Line Emission as a Tracer of Nonradiative Preionized Shocks: Application to Winds and Circumstellar Disks in the Orion Nebula

Patrick Hartigan

Space Physics and Astronomy Dept., Rice University, 6100 S. Main, Houston TX 77005-1892, USA

E-mail contact: hartigan@sparky.rice.edu

Collisionally-excited Balmer line emission from H occurs whenever neutral hydrogen enters a sufficiently strong shock. Such emission has many important applications for the study of Herbig-Haro objects and supernova remnants. This paper explores the collisional excitation and ionization of the H-like ion He II in shocks, a process that may prove to be useful in cases where no Balmer emission from H occurs because the preshock H is completely ionized. Like the Balmer lines of H, Balmer lines of He II also radiate owing to collisional excitation at the shock, though the complexities of broad and narrow components present in the H lines should be absent in He II emission.

New narrowband images of the Trapezium region of Orion in He II λ4686 and the adjacent continuum near this wavelength fail to show any He II emission signatures from shocks. Upper limits on the He II fluxes in these images, combined with predictions of the brightness of He II λ4686 in nonradiative shocks give an upper limit to the mass outflow rate from Θ^1Ori C consistent with the mass loss rate estimated from UV observations. The new images show that HH 202 represents the superposition of two bow shocks moving in opposite directions, which explains some anomalies seen previously in emission line images of this source taken with HST.

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A copy of the paper is available at http://sparky.rice.edu/∼hartigan/pub.html.

Submillimeter Maps of Bok Globule Cores: Evidence for Multiple Epoch Star Formation

Tracy L. Huard[1], Göran Sandell[2] and David A. Weintraub[1]

[1] Department of Physics & Astronomy, Vanderbilt University, P.O. Box 1807 Station B, Nashville, TN 37235, USA
[2] National Radio Astronomy Observatory, P.O. Box 2, Green Bank, WV 24944, USA

E-mail contact: huard@juggler.phy.vanderbilt.edu

We mapped 15 cold IRAS sources associated with Bok globules, using the submillimeter common user bolometer array SCUBA on the JCMT, in order to search for deeply embedded protostars. Submillimeter emission was detected in six of these globules, five of which contain one or more compact sources. We detected a total of seven compact submillimeter sources. At least five of these, which have no known near-infrared counterparts, are candidate or confirmed Class 0 sources. The IRAS sources detected in the submillimeter have IRAS colors consistent with those of dense molecular cloud cores and/or outflow sources, whereas the IRAS sources not detected in this survey have IRAS colors consistent with those of infrared cirrus.

We present compelling evidence that multiple star formation has occurred in four of the six Bok globules which we have detected in the submillimeter; thus, the formation of a single star in isolation from other stars appears to be a rare event in Bok globules. These four globules contain two or three young stellar objects, sometimes at very different evolutionary stages. Two Bok globules, CB 68 and CB 232, are found to contain a candidate Class 0 source in addition

to a more evolved Class I or Class II pre-main-sequence star. These observations, in which we find a Class 0 protostar and a pre-main-sequence star in the same globule, suggest that multiple epochs of star formation are possible in Bok globules.

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http://comped1.cas.vanderbilt.edu/ huard/home.html

Nonaxisymmetric Dynamic Instabilities of Rotating Polytropes. II. Torques, Bars, and Mode Saturation with Applications to Protostars and Fizzlers

James N. Imamura[1], Richard H. Durisen[2], and Brian K. Pickett[3]

[1] Institute of Theoretical Science, University of Oregon, Eugene, OR 97403,USA
[2] Department of Astronomy, Indiana University, Bloomington, IN 47405, USA
[3] Ames Research Center, MS 245-3, Moffett Field, CA 94035, USA

E-mail contact: imamura@herb.uoregon.edu

Dynamic nonaxisymmetric instabilities in rapidly rotating stars and protostars have a range of potential applications in astrophysics, including implications for binary formation during protostellar cloud collapse and for the possibility of aborted collapse to neutron star densities at late stages of stellar evolution ("fizzlers"). We have recently presented detailed linear analyses for polytropes of the most dynamically unstable global modes, the barlike modes. These produce bar distortions in the regions near the rotation axis but have trailing spiral arms toward the equator. In this paper, we use our linear eigenfunctions to predict the early nonlinear behavior of the dynamic instability and compare these "quasi-linear" predictions with several fully nonlinear hydrodynamics simulations. The comparisons demonstrate that the nonlinear saturation of the barlike instability is due to the self-interaction gravitational torques between the growing central bar and the spiral arms, where angular momentum is transferred outward from bar to arms. We also find a previously unsuspected resonance condition which accurately predicts the mass of the bar regions in our own simulations and in those published by other researchers. The quasi-linear theory makes other accurate predictions about consequences of instability, including properties of possible endstate bars and increases in central density, which can be large under some conditions. We discuss in some detail the application of our results to binary formation during protostellar collapse and to the formation of massive rotating black holes.

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Forming the Dusty Ring in HR 4796A

Scott J. Kenyon[1], Kenneth Wood[1], Barbara A. Whitney[2], and Michael J. Wolff[2]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138 USA
[2] Space Science Institute, Suite 23, 1540 30th Street, Boulder, CO 80303-1012 USA

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

We describe planetesimal accretion calculations for the dusty ring observed in the nearby A0 star HR 4796A. Models with initial masses of 10–20 times the minimum mass solar nebula produce a ring of width 7–15 AU and height 0.3–0.6 AU at 70 AU in $\sim$ 10 Myr. The ring has a radial optical depth $\sim$ 1. These results agree with limits derived from infrared images and from the excess infrared luminosity.

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The Circumstellar Environment of UX Ori

A. Natta[1], T. Prusti[2], R. Neri[3], W.F. Thi[4], V.P. Grinin[5,6], and V. Mannings[7]

[1] Osservatorio Astrofisico di Arcetri, Largo E.Fermi 5, I-50125 Firenze, Italy
[2] ISO Data Centre, Astrophysics Division, Space Science Department of ESA, Villafranca del Castillo, P.O. Box 50727, E-28020 Madrid, Spain
[3] IRAM, 300 Rue de la Piscine, Domaine Universitaire, F-38406 St. Martin d'Hères Cedex, France

[4] Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands
[5] Crimean Astrophysical Observatory, Crimea, 334413 Nauchny, Ukraine
[6] St. Petersburgh University, St. Petersburgh, 198904, Russia
[7] JPL, California Institute of Technology, MS 169-327, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

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

This paper presents new observations of UX Ori obtained with the millimeter interferometer of Plateau de Bure and with ISO. UX Ori is the prototype of a group of pre-main–sequence, intermediate-mass stars, often indicated as precursors of β Pic. The interferometry observations at 1.2 and 2.6mm show that UX Ori has a circumstellar disk, with outer radius $\lesssim$ 100 AU. We determine the spectral index between these two wavelengths to be 2.1±0.2, consistent with the disk being optically thick at mm wavelengths. Alternatively, the disk solid matter can be in the form of "pebbles" (radius∼10 cm). In both cases most of the disk mass must be in gas form, and small grains must be present, at least in the disk atmosphere. In both cases also, the disk must be rather massive ($\gtrsim$ 0.1 $M_\odot$). The existence of a circumstellar disk supports the model of the UXOR phenomenon in terms of a star+disk system. Self-consistent models of almost edge-on disks account well for the observed emission at all wavelengths longer than about 8μm, if we include the emission of the optically thin, superheated layers that enshroud the disk. These rather simple disk models fail to account for the strong emission observed in the near-IR (i.e., between $\sim$ 2 and 7 μm), and we suggest a number of possible explanations.

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Dynamics of Circumstellar Disks II: Heating and Cooling

Andrew F. Nelson[1,2], Willy Benz[3,4], Tamara V. Ruzmaikina[5]

[1] Department of Physics, The University of Arizona, Tucson AZ 85721, USA
[2] Max Planck Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[3] Physikalisches Institut, Universität Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland
4 Steward Observatory, The University of Arizona, Tucson AZ 85721, USA
5 Lunar and Planetary Laboratory, The University of Arizona, Tucson AZ 85721, USA

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

We present a series of 2-dimensional (r, ϕ) hydrodynamic simulations of marginally self gravitating disks (M_D/M_*=0.2, with $M_* = 0.5 M_\odot$ and with disk radius $R_D = 50$ and 100 AU) around protostars using a Smoothed Particle Hydrodynamic (SPH) code. We implement simple and approximate prescriptions for heating via dynamical processes in the disk. Cooling is implemented with a simple radiative cooling prescription which does not assume that local heat dissipation exactly balances local heat generation. Instead, we compute the local vertical (z) temperature and density structure of the disk and obtain a 'photosphere temperature', which is then used to cool that location as a black body. We synthesize spectral energy distributions (SEDs) for our simulations and compare them to fiducial SEDs derived from observed systems, in order to understand the contribution of dynamical evolution to the observable character of a system.

We find that these simulations produce less distinct spiral structure than isothermally evolved systems, especially in approximately the inner radial third of the disk. Pattern amplitudes are similar to isothermally evolved systems further from the star but do not collapse into condensed objects. We attribute the differences in morphology to increased efficiency for converting kinetic energy into thermal energy in our current simulations. Our simulations produce temperatures in the outer part of the disk which are very low ($\sim$ 10 K). The radial temperature distribution of the disk photosphere is well fit to a power law with index $q \sim 1.1$. Far from the star, corresponding to colder parts of the disk and long wavelength radiation, known internal heating processes (PdV work and shocks) are not responsible for generating a large fraction of the thermal energy contained in the disk matter. Therefore gravitational torques responsible for such shocks cannot transport mass and angular momentum efficiently in the outer disk.

Within ∼5–10 AU of the star, rapid break up and reformation of spiral structure causes shocks, which provide sufficient dissipation to power a larger fraction of the near infrared radiated energy output. In this region, the spatial and size distribution of grains can have marked consequences on the observed near infrared SED of a given disk, and can lead to increased emission and variability on $\lesssim$ 10 year time scales. The inner disk heats to the destruction temperature of dust grains. Further temperature increases are prevented by efficient cooling when the hot disk midplane is exposed. When grains are vaporized in the midplane of a hot region of the disk, we show that they do not reform into a size distribution similar to that from which most opacity calculations are based. With rapid grain reformation into the original size distribution, the disk does not emit near infrared photons. With a plausible modification of the opacity, it contributes much more.

Accepted by the ApJ

Preprints are available at http://www.mpia-hd.mpg.de/theory/andy/publications.html

Medium-resolution optical spectroscopy of young stellar and sub-stellar M-dwarfs in the Cha I dark cloud

Ralph Neuhäuser[1] **and Fernando Comerón**[2]

[1] MPI für extraterrestrische Physik, Giessenbachstraße 1, D-85740 Garching, Germany
[2] European Southern Observatory, Karl-Schwarzschild-Straße 2, D-85748 Garching, Germany

E-mail contact: rne@mpe.mpg.de

We obtained medium-resolution spectra of the bona-fide brown dwarf Cha Hα 1, the five brown dwarf candidates Cha Hα 2 to 6, two additional late M-type brown dwarf candidates, all originally selected by Hα emission, and four previously known T Tauri stars, all located in Chamaeleon I. The spectral types of our targets range down to M8. We show their spectra and also list their IJK magnitudes from DENIS. All objects have radial velocities consistent with kinematic membership to Cha I and show Li 6708Å absorption. Our Cha I brown dwarf candidates with lithium are young or sub-stellar or both. Cha Hα 1, 3, 6, and 7 are certainly brown dwarfs: Either they are as old or older than the Pleiades and should have burned all their original lithium if they were late M-type stars, or, if they are younger than the Pleiades, $\leq$ 125 Myrs, they are sub-stellar because of the young age and the late spectral types ($\geq$ M7), according to three different sets of evolutionary tracks and isochrones. To classify Cha Hα 2, 4, 5, and 8 as either stellar or sub-stellar, evolutionary tracks of higher reliability are needed.

Accepted by Astronomy & Astrophysics

pre-print at astro-ph/9908265

An L-type substellar object in Orion: reaching the mass boundary between brown dwarfs and giant planets

M. R. Zapatero Osorio[1]**, V. J. S. Béjar**[1]**, R. Rebolo**[1]**, E. L. Martín**[2] **and G. Basri**[2]

[1] Instituto de Astrofísica de Canarias, E–38200 La Laguna, Tenerife, Spain
[2] Dept. of Astronomy, 601 Campbell Hall, Univ. of California, Berkeley, CA 94720 USA

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

We present near-infrared photometry (J-band) and low-resolution optical spectroscopy (600–1000 nm) for one of the faintest substellar member candidates in the young σ Orionis cluster, S Ori 47 (I = 20.53, Béjar et al. 1999). Its very red $(I-J)=3.3\pm0.1$ color and its optical spectrum allow us to classify S Ori 47 as an L1.5-type object which fits the low-luminosity end of the cluster photometric and spectroscopic sequences. It also displays atmospheric features indicative of low gravity such as weak alkaline lines and hydride and oxide bands, consistent with the expectation for a very young object still undergoing gravitational collapse. Our data lead us to conclude that S Ori 47 is a true substellar member of the σ Orionis cluster. Additionally, we present the detection of Li I in its atmosphere which provides an independent confirmation of youth and substellarity. Using current theoretical evolutionary tracks and adopting an age interval of 1–5 Myr for the σ Orionis cluster, we estimate the mass of S Ori 47 at $0.015\pm0.005\,M_\odot$, i.e. at the minimum mass for deuterium burning, which has been proposed as a definition for the boundary between brown dwarfs and giant planets. S Ori 47 could well be the result of a natural extension of the process of cloud fragmentation down to the deuterium burning mass limit; a less likely alternative is that it has originated from a protoplanetary disc around a more massive cluster member and later ejected from its orbit due to interacting effects within this rather sparse ($\sim$12 objects pc^{-3}) young cluster. The study of this object serves as a guide for future deep searches for free-floating objects with planetary masses.

Accepted by ApJ Letters

The Effects of Thermal Energetics on 3D Hydrodynamic Instabilities in Massive Protostellar Disks. II. High Resolution and Adiabatic Evolutions

Brian K. Pickett[1,2,3], Patrick Cassen[1], Richard H. Durisen[4,5], and Robert Link[4]

[1] NASA's Ames Research Center, M.S. 245-3, Moffett Field, CA 94710, USA
[2] Also: University of California at Berkeley
[3] Current address: Department of Physics and Astronomy, Niels Science Center, Valparaiso, Indiana, 46383, USA
[4] Department of Astronomy, Indiana University, Bloomington, IN 47405, USA
[5] Also: Max-Planck-Institut für Extraterrestriche Physik, 857 40 Garching, Germany

E-mail contact: pickett@cosmic.arc.nasa.gov

In this paper, the effects of thermal energetics on the evolution of gravitationally unstable protostellar disks are investigated by means of three-dimensional hydrodynamic calculations. The initial states for the simulations correspond to stars with equilibrium, self-gravitating disks which are formed early in the collapse of a uniformly rotating, singular isothermal sphere. In a previous paper (Pickett *et al.* 1998), it was shown that the nonlinear development of locally isentropic disturbances can be radically different than that of locally isothermal disturbances, even though growth in the linear regime may be similar. When multiple low-order modes grew rapidly in the star and inner disk region and saturated at moderate nonlinear levels in the isentropic evolution, the same modes in the isothermal evolution led to shredding of the disk into dense arclets and the ejection of material. In this paper, we (1) examine the fate of the shredded disk with calculations at higher spatial resolution than the previous simulations and (2) follow the evolution of the same initial state using an internal energy equation, rather than the assumption of locally isentropic or locally isothermal conditions.

Despite the complex structure of the nonlinear features which developed in the violently unstable isothermal disk referred to above, our previous calculation produced no gravitationally independent, long-lived, stellar or planetary companions. The higher resolution calculations presented here confirm this result. When the disk of this model is cooled further, prompting even more violent instabilities, the end result is qualitatively the same a shredded disk. At least for the disks studied here, it is difficult to produce condensations of material that do not shear away into fragmented spirals. It is argued that the ultimate fate of such fragments depends on how readily local internal energy is lost.

On the other hand, if a dynamically unstable disk is to survive for very long times without shredding, then some mechanism must mitigate and control any violent phenomena that do occur. The prior simulations demonstrated a marked difference in final outcome depending upon the efficiency of disk cooling under two different, idealized thermal conditions. We have here incorporated an internal energy equation which allows for arbitrary heating and cooling. Simulations are presented for adiabatic models with and without artificial viscosity. The artificial viscosity accounts for dissipation and heating due to shocks in the code physics. The expected nonaxisymmetric instabilities occur and grow as before in these energy equation evolutions. When artifical viscosity is not present, the model protostar displays behavior intermediate between the locally isentropic and locally isothermal cases of the last paper; a strong two-armed spiral grows to nonlinear amplitudes and saturates at a level higher than the locally isentropic case. Since the amplitude of the spiral disturbance is large, it is expected that continued transport of material and angular momentum will occur well after the end of the calculation at nearly four outer rotation periods. The spiral is not strong enough, however, to disrupt the disk as in the locally isothermal case. When artificial viscosity is present, the same disturbances reach moderate nonlinear amplitude, then heat the gas, which in turn greatly reduces their strength and effects on the disk. Additional heating in the low density regions of the disk also lead to a gentle flow of material vertically off the computational grid. The energy equation and high resolution isothermal calculations are used to discuss the importance and relevance of the different thermal regimes so far examined, with particular attention to applications to star and planet formation.

Accepted by Astrophys. J.

First Detection of Submillimeter Polarization from T Tauri Stars

Motohide Tamura[1], J. H. Hough[2], J. S. Greaves[3], Jun-Ichi Morino[4], Antonio Chrysostomou[2,3], W. S. Holland[3], Munetake Momose[5]

[1] National Astronomical Observatory, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan
[2] University of Hertfordshire, Hatfield, Hertfordshire AL10 9AB, UK

[3] Joint Astronomy Centre, 660 N. A'ohoku Place, University Park, Hilo, HI 96720, USA
[4] University of Tokyo, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan
[5] Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-1305, Japan

E-mail contact: tamuramt@cc.nao.ac.jp

We report a first detection of polarization of the 850 μm continuum emission from two T Tauri stars (TTSs), GM Aur and DG Tau. These are both single and classical TTSs. The emission mostly comes from the compact (r < 100 AU) accretion disks. The polarization (at about 3 % level at 3 σ) is interpreted in terms of thermal emission by magnetically aligned dust grains in the disk. Thus these submillimeter polarizations probe the magnetic field structure in the disk, while the previously reported millimeter/submillimeter polarizations of protostars and the transitional objects from the protostars to TTSs, trace the magnetic fields in the larger envelope region. In both TTSs, the direction of the magnetic field inferred from our submillimeter polarizations is parallel to the plane of the compact dust disk measured by interferometric observations, suggesting the dominance of a toroidal magnetic field component in the disk. The magnetic evolution of the circumstellar environments is discussed as well as the constraints on the MHD models of the jets and outflows from young stellar objects.

Accepted by Astrophys. J.

Detection of new sources of methanol emission at 107 and 108 GHz with the Mopra telescope

I.E. Val'tts,[1] S.P. Ellingsen,[2] V.I. Slysh,[1] S.V. Kalenskii,[1] R. Otrupcek[3] and M.A. Voronkov[1]

[1] Astro Space Center of Lebedev Physical Institute, Profsoyuznaya 84/32, 117810 Moscow, Russia
[2] School of Mathematics and Physics, University of Tasmania, GPO Box 252-21, Hobart 7001, TAS, Australia
[3] Australia Telescope National Facility, PO Box 76, Epping 2121, NSW, Australia

E-mail contact: Simon.Ellingsen@utas.edu.au

A southern hemisphere survey of methanol emission sources in two millimeter wave transitions has been carried out using the ATNF Mopra millimetre telescope. Sixteen emission sources have been detected in the $3_1 - 4_0 A^+$ transition of methanol at 107 GHz, including six new sources exhibiting class II methanol maser emission features. Combining these results with the similar northern hemisphere survey, a total of eleven 107-GHz methanol masers have been detected. A survey of the methanol emission in the $0_0 - 1_{-1} E$ transition at 108 GHz resulted in the detection of 16 sources; one of them showing maser characteristics. This is the first methanol maser detected at 108 GHz, presumably of class II. The results of LVG statistical equilibrium calculations confirm the classification of these new sources as a class II methanol masers.

Accepted by MNRAS

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The temperature of non-spherical interstellar grains

N.V. Voshchinnikov[1], D.A. Semenov[1] and Th. Henning[2]

[1] Sobolev Astronomical Institute, St. Petersburg University, St. Petersburg, 198904 Russia
[2] Astrophysical Institute and University Observatory, Friedrich Schiller University, Schillergäßchen 3, D-07745 Jena, Germany

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

A model of spheroidal particles is used to calculate the steady-state temperature of dust grains immersed in the interstellar radiation field. It is found that the temperature of non-spherical grains with the aspect ratios $a/b \lesssim 2$ deviates from that of spheres less than 10 %. More elongated or flattened particles are usually cooler than spheres of the same mass and in some cases the temperatures may differ by even about a factor of 2. The shape effects increase with the infrared absorptivity of the grain material and seem to be more important in dark interstellar clouds.

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Calculating Cross Sections of Composite Interstellar Grains

Nikolai V. Voshchinnikov[1] **and John S. Mathis**[2]

[1] Sobolev Astronomical Institute, St. Petersburg University, St. Petersburg, 198904 Russia
[2] Dept. of Astronomy, Univ. of Wisconsin; 475 N. Charter St., Madison WI 53706, USA

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

Interstellar grains may be composite collections of particles of distinct materials, including voids, agglomerated together. We determine the various optical cross sections of such composite grains, given the optical properties of each constituent, using an approximate model of the composite grain. We assume it consists of many concentric spherical layers of the various materials, each with a specified volume fraction. In such a case the usual Mie theory can be generalized and the extinction, scattering, and other cross sections determined exactly.

We find that the ordering of the materials in the layering makes some difference to the derived cross sections, but averaging over the various permutations of the order of the materials provides rapid convergence as the number of shells (each of which is filled by all of the materials proportionately to their volume fractions) is increased. Three shells, each with one layer of a particular constituent material, give a very satisfactory estimate of the average cross section produced by larger numbers of shells.

We give the formulae for the Rayleigh limit (small size parameter) for multi-layered spheres and use it to propose an "Effective Medium Theory" (EMT), in which an average optical constant is taken to represent the ensemble of materials.

Multi-layered models are used to compare the accuracies of several EMTs already in the literature. EMTs are worse for predicting scattering cross sections than extinction, and considerably worse for predicting g, the mean cosine of the angle of scattering. However, the angular distribution of the scattered radiation depends sensitively on the assumed grain geometry and should be taken with caution for any grain theory. Our computation is vastly simpler than discrete multipole calculations and may be easily applied for practical modeling of the extinction and scattering properties of interstellar grains.

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Extinction and polarization of radiation by absorbing spheroids: shape/size effects

N.V. Voshchinnikov[1]**, V.B. Il'in**[1]**, Th. Henning**[2]**, B. Michel**[2] **and V.G. Farafonov**[3]

[1] Sobolev Astronomical Institute, St. Petersburg University, St. Petersburg, 198904 Russia
[2] Astrophysical Institute and University Observatory, Friedrich Schiller University, Schillergäßchen 3, D-07745 Jena, Germany
[3] St. Petersburg University of Aerocosmic Instrumentation, St. Petersburg, 190000 Russia

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

We use the separation of variables and T-matrix methods to calculate the optical properties of homogeneous spheroids with refractive indices from $m = 1.3 + 0.0i$ up to $3 + 4i$.

It is found that the extinction cross-sections for highly absorbing spheroids are normally $1.5 - 2$ times larger than those for spheres of the same volume. The albedo of the non-spherical particles rather slightly depends on the particle shape and is mainly determined by the imaginary part of the refractive index. Beginning at some size, the spheroidal particles do not polarize the transmitted radiation independent of their shape.

We also suggest a new approach for axisymmetric particles which would combine the strong aspects of both methods mentioned above and give several values of the cross-sections as benchmarks in tabular form.

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Studies of Ultracompact HII Regions – III. Near-Infrared Survey of Selected Regions

A. J. Walsh[1,2], M. G. Burton[1], A. R. Hyland[3] and G. Robinson[4]

[1] Department of Astrophysics and Optics, School of Physics, University of New South Wales, NSW 2052, Australia
[2] Max-Planck-Institut für Radioastronomie, auf dem Hügel 69, D-53121, Bonn, Germany
[3] Southern Cross University, Lismore, NSW 2480, Australia
[4] School of Physics, University College, University of New South Wales, Canberra, ACT, 2600, Australia

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

A survey towards a selection of 35 methanol maser and/or ultracompact (UC) HII regions, reported in Papers 1 and 2 and by Norris et al. (1993), has been conducted in the near-infrared. Out of 25 methanol maser sites surveyed, 12 are associated with a NIR counterpart. Out of 18 UC HII regions (8 of which overlap with maser emission), 12 are associated with a NIR counterpart. Counterparts can be confidently identified not only by the positional agreements, but also by their unusually red colours. Spectral types for the embedded stars can be unambiguously determined for six sources, all of which imply massive, ionising stars. One of these infrared sources has methanol maser emission, but no UC HII region. It is possible that the maser emission associated with this source arises from a pre-UC HII phase of massive stellar evolution or it could be that nearly all the UV photons are absorbed by dust within the UC HII region. We have modelled the spectral energy distributions (SEDs) for some sources and find that a single blackbody can be used to estimate the stellar luminosity, but cannot represent the whole infrared SED. A two-component blackbody model and a radiative transfer model were also used to derive essential parameters of the infrared sources. The radiative transfer model also indicates which infrared sources are relatively young and which are older. Both models show that silicate absorption at 9.7 microns must be a dominant feature of these SEDs.

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Preprint available at: ftp://ftp.mpifr-bonn.mpg.de/pub/user/awalsh/paper3/

High-resolution spectroscopy of ROSAT-discovered WTTSs near Lupus

R. Wichmann,[1,3] E. Covino,[2] J.M. Alcalá,[2,6] J. Krautter,[3] S. Allain,[4] P.H. Hauschildt[5]

[1]IUCAA, Post Bag 4, Ganeshkhind, Pune 411007, India
[2]Osservatorio Astronomico di Capodimonte, Napoli, Italy
[3]Landessternwarte Königstuhl, D-69117 Heidelberg, Germany
[4]Laboratoire d'Astrophysique, Observatoire de Grenoble, Universite Joseph Fourier - B.P.53,
F-38041 Grenoble Cedex 9, France
[5]University of Georgia, Athens, GA 30602-2451, USA
[6]Instituto Nacional de Astrofísica, Optica y Electrónica, A.P. 51 y 216, C.P. 72000, Puebla, México

E-mail contact: rwichmann@hs.uni-hamburg.de

We present high-resolution optical echelle spectroscopy for a large fraction of the Li-rich late-type stars recently discovered in the vicinity of the Lupus dark clouds. Our results confirm the high Li I λ6708 equivalent widths as previously estimated from medium-resolution spectra, thus adding further strength to the conclusion that the large majority of these stars are still in the pre-main sequence phase of their evolution, contrary to claims from other authors that many of them might be zero-age main sequence stars. We present a statistical approach to derive a mean distance for the sample, and find that it is consistent with, or slightly lower than, the *HIPPARCOS* distance of the Lupus star forming region. The radial velocities measured for part of these stars are consistent with those observed for the Lupus star forming region, while stars outside the dark clouds show a mean difference on the order of $3\,\mathrm{km\,s^{-1}}$. The projected rotational velocities show a lack of slow rotators, which is interpreted as a consequence of the X-ray selection of the sample. The Li-rich stars in Lupus studied in this work yield a rather 'clean' sample of very young stars, while in other star forming regions a larger fraction of older ZAMS stars has been found among *ROSAT*-discovered Li-rich stars. We argue that this fact reflects the relation of these stars with the Gould Belt.

Accepted by MNRAS

Dissertation Abstracts

Dynamics and Observational Appearance of Circumstellar Disks

Andrew F. Nelson

Thesis work conducted at: Steward Observatory, University of Arizona, USA

Current address: Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany

Electronic mail: andy@mpia-hd.mpg.de

Ph.D dissertation directed by: Willy Benz

Ph.D degree awarded: 5/99

In my thesis I present a study of the dynamics and observational characteristics of massive circumstellar disks in two dimensions (r, ϕ) using two complimentary hydrodynamic codes: a 'Smoothed Particle Hydrodynamic' (SPH) code and a 'Piecewise Parabolic Method' (PPM) code. I also study the detection limits available to radial velocity searches for low mass companions to main sequence stars. This thesis is organized as a series of published or submitted papers, connected by introductory and concluding material. I strongly recommend that readers of this abstract obtain the published versions of each of these papers.

I first outline the progress which has been made in the modeling of the structure and origins of the solar system, then in chapter 2 (*The Astrophysical Journal* v502, p342, with W. Benz, F. Adams and D. Arnett), I proceed with numerical simulations of circumstellar disks using both hydrodynamic codes assuming a 'locally isothermal' equation of state. The disks studied range in mass from $0.05M_*$ to $1.0M_*$ and in initial minimum Toomre Q value from 1.1 to 3.0. Massive disks ($M_D > 0.2M_*$) tend to form grand design spiral structure with 1–3 arms, while low mass disks ($M_D \leq 0.2M_*$) tend to form filamentary, >4 armed spiral structures. Disks with minimum Toomre stability $Q \lesssim 2.0$ are dynamically active and structures within each disk become distorted, break apart and reform on orbital time scales. Spiral arms in disks with $Q \lesssim 1.5$ frequently collapse into clumps. I perform a detailed comparison of the two numerical techniques employed and conclude that SPH is unable to follow the linear instability regime of the disk systems due to noise inherent in the method.

In chapter 4 (submitted to *The Astrophysical Journal* with W. Benz and T. Ruzmaikina), I relax the assumption the locally isothermal evolution assumption and instead include simple heating and cooling prescriptions for the system. Under these physical conditions, the spiral arm growth is suppressed in the inner 1/3 of the disks relative to the isothermal evolution and in the remainder, changes character to more diffuse spiral structures. I synthesize spectral energy distributions (SEDs) from the simulations and compare them to fiducial SEDs derived from observed systems. The size distribution of grains in the inner disk can have marked consequences on the near infrared portion of the SED. After being vaporized in a hot midplane region, the grains do not reform quickly into the size distribution on which most opacity calculations are based. With the original opacities, near infrared emission suppressed relative to observations, with a plausible modification to the opacity, a more realistic SED is obtained. At long wavelengths, insufficient flux is produced and we conclude that the internal heating processes included in our model (due e.g. to gravitational torques) do not provide a large fraction of the thermal energy present in the outer portions of accretion disks.

In chapter 6 (*The Astrophysical Journal* v500, p940 with Roger Angel), I examine the limits which may be placed upon the detection of planets, brown dwarfs and low mass stellar companions using radial velocity measurements. I derive an analytic expression describing the amplitude limits for periodic signals which may be obtained from a set of data of known duration, number of measurements and precision. I have verified the formalism with Monte Carlo experiments and outlined the regions of its validity. I have used the technique to suggest a strategy for continuing large radial velocity searches for low mass companions.

In chapter 7, I outline several problems which may be profitably addressed by building on this work.

Postscript version available at http://www.mpia-hd.mpg.de/theory/andy/publications.html

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Application review will begin September 15, 1999 and continue until the positions are filled. The Max Planck Society is an equal opportunity employer.

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

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New Books

The Origins of Stars and Planetary Systems

Editors C.J. Lada and N.D. Kylafis

The Origins of Stars and Planetary Systems is a collection of tutorial reviews which in a comprehensive way discuss the current state of knowledge of star formation and early stellar evolution: from the genesis of giant molecular clouds to the birth of young stars and their surrounding planetary systems. This book is both the sequel and successor to the well known *The Physics of Star Formation and Early Stellar Evolution* which was published by the same editors in 1991 and was a key reference book for many years. Similar to the earlier volume, the chapters of this book are written at the graduate student level with an emphasis placed on fundamentals rather than recent results. The book provides a rigorous treatment of the basic empirical and theoretical foundations of modern star formation research, and is intended for use as a text for a graduate course on star formation or as a basic reference for the professional scientist.

The chapters of the book are listed below, and can be downloaded from the web at http://cfa-www.harvard.edu/crete/

Molecular Clouds *L. Blitz & J. P. Williams*
The Dynamical Structure and Evolution of Giant Molecular Clouds *C.F. McKee*
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- Dispersed young stellar populations
- Feedback effects on star formation

Scientific Organizing Committee: I. Bonnell (Cambridge, UK), J. Bouvier (Grenoble), E.D. Feigelson (Penn State), Y. Fukui (Nagoya), K. Koyama (Kyoto), C. McKee (Berkeley), T. Montmerle (Saclay, Chair), A. Natta (Florence), R. Pallavicini (Palermo), R. Rebolo (Tenerife), P. Saraceno (Rome), H. Zinnecker (Potsdam)

Local Organizing Committee (Saclay): P. André, J.-P. Chièze, P.-O. Lagage, T. Montmerle

Because of space limitations, attendance will be limited to about 80.

Application forms and a call for papers will be included in the First Circular, due end of October. This circular will appear on our web-page at http://www.phys.ens.fr/cargese/

The conference is the third in the series of the "Three-Island" Euroconferences on Clusters and Associations, partially funded by the European Community. The two previous "Three-Island" Euroconferences were:

1- *Very Low-mass Stars in Clusters and Associations*

La Palma (Canary Islands, Spain; Chair: R. Rebolo), May 11-15, 1998

2- *Stellar Clusters and Associations: Convection, Rotation, and Dynamos*

Mondello (Sicily, Italy; Chair: R. Pallavicini), May 25-28, 1999

Limited support from the European Community will be available for Cargese, but is reserved for citizens of its member countries. Additional support is being sought, but cannot be guaranteed at the present time. Prospective participants are encouraged to look for sources of their own.

Contact: montmerle@cea.fr

Further information will appear on our web site as it becomes available:

http://www.phys.ens.fr/cargese/

FIRST ANNOUNCEMENT

IAU Symposium 200: The Formation of Binary Stars

April 10–15, 2000: Potsdam, Germany

The IAU has approved the holding of a symposium on "The Formation of Binary Stars" to take place from April 10–15, 2000, in Potsdam, Germany. Potsdam is located about 30 km southwest of the centre of Berlin, and the Astrophysical Institute Potsdam (AIP) will host the conference at its Telegraphenberg site.

There has never been an IAU-sponsored symposium on young binary stars, understandable given that a decade ago only a few young binaries were known. However, it is now clear that binary stars are a central theme of star formation and merit a comprehensive discussion at the level of an IAU symposium.

The symposium will include many invited talks covering both theory and observations of binary star formation, as well as an extensive poster session. Major topics will include:

- Cloud fragmentation and collapse
- Proto-binaries and infrared companions
- Main sequence and pre-main sequence binary populations
- Environments of young binaries; accretion disks and jets
- Dynamical evolution of young binaries
- Binaries as tests of pre-main sequence stellar evolution models
- Planet formation in binary systems
- Frontiers of observation and theory in the study of binary formation

Potsdam has a long tradition in binary star research dating back to Hermann Carl Vogel, who measured the radial velocities for hundreds of bright stars at the turn of the century. This line of research also led to the discovery of stationary Calcium H and K lines in the spectrum of the δ Ori binary system by Johannes Hartmann with the Potsdam double refractor, and thence to the discovery of the interstellar medium. Thus the connection of binary stars and their origin in interstellar clouds is nicely established in Potsdam. Furthermore, the AIP, as the successor of the old Berlin Sternwarte founded in 1700, will celebrate its 300th anniversary in the year of the symposium.

Scientific Organizing Committee:
H. Zinnecker (co-chair), R. D. Mathieu (co-chair), P. Artymowicz, A. Boss, J. Bouvier, C. Clarke, A. Dutrey, A. Ghez, P. Kroupa, C. Leinert, S. Miyama, B. Reipurth, M. Simon, A. Tokovinin, and A. Whitworth.

Contact information:
The symposium website (`http://www.aip.de/IAU200/`) will soon include full details on registering for the conference, arranging accommodation, how to reach Potsdam, and so on. In the meantime, preliminary interest in attending the meeting should be expressed by sending email to `iau200@aip.de`; further announcements concerning the meeting will be made via e-mail and the IAU200 website.

If you have any additional questions, please contact Hans Zinnecker at:
Astrophysikalisches Institut Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany;
Phone: +49 (0)331 7499 347; Fax: +49 (0)331 7499 267; e-mail: hzinnecker@aip.de

STAR FORMATION 2000: From Protostellar Cores to Stars and Planetary Systems

hosted by the **Max-Planck-Institut for Astronomy (Heidelberg) and the Astrophysical Institute (Jena)**

Ringberg Castle, Tegernsee, June 21–24, 2000

For registration, please send an email to Andi Burkert (burkert@mpia-hd.mpg.de) or check the WEB-page at http://www.mpia-hd.mpg.de/MPIA/. . Further announcements will be sent to all those who preregistered.

Brief Motivation

Observations and theory have lead to substantial progress over the past years in our understanding of the formation, dynamical evolution, collapse and fragmentation of protostellar cores and the formation of stars and planetary systems. This workshop intends to bring together observers and theorists working in the field of *low mass* star formation, protostellar disk evolution and planet formation in order to identify and discuss both, the progress and the lack in our understanding of star and planet formation.

The programme is tentatively subdivided into the following sessions:

- Formation and structure of protostellar cores as initial conditions for star formation.
- Quasistatic, magnetically supported evolution of cores, dynamical core collapse and fragmentation.
- Protostellar disk evolution - dynamics, turbulence, viscosity
- Protostellar disk evolution - chemistry and grain growth
- Interaction of protostellar disks with the environment
- Planet formation and disk-planet interaction
- Formation of brown dwarfs

SCIENTIFIC ORGANIZING COMMITTEE

P. Bodenheimer, A. Burkert, A. Burrows, Th. Henning, L. Mundy, C.F. McKee, F. Palla, J. Stone, H.W. Yorke

LOCAL ORGANIZING COMMITTEE

A. Burkert (chair), Th. Henning, O. Kessel, J. Steinacker

The workshop will take place at the Ringberg castle, the conference resort of the Max-Planck-Society in Bavaria, near Tegernsee (WWW-Site: http://www.rzg.mpg.de/ringberg-castle). The total number of participants is constrained by the limited number of rooms at the Ringberg castle. Registered speakers will be invited on the basis of the recommendations of the SOC.

Contact Address

Dr. Andreas Burkert
Max-Planck-Institute for Astronomy
Königstuhl 17
D-69117 Heidelberg
Germany

Fax: (49) 6221528226 (attn: A. Burkert)
E-mail: burkert@mpia-hd.mpg.de
http://www.mpia-hd.mpg.de