

# THE STAR FORMATION NEWSLETTER

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

No. 125 — 14 March 2003

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## *From the Editor*

From time to time, major reviews on topics relevant for the star formation community are published. As of this issue of the Star Formation Newsletter, there will be a section specifically for abstracts from such major reviews. For these abstracts of major reviews, it is a requirement that a web address is provided with the abstract. I want to note that the emphasis here is on major. What I have in mind are chapters for Annual Reviews, for Protostars and Planets conferences, for NATO Advanced Study Institutes, for Saas-Fee or Les Houches lectures, or similar types of large scale effort. The section is not meant to include the standard 4 or 10 page contributions to various meetings, as for example commonly published by ASP. This is not a judgement on quality or usefulness, but a recognition that I simply would not have the time to handle the production of the Newsletter if it doubled in size by all the abstracts from the many meetings that take place all the time.

I also want to draw attention to the Short Announcements section, which occasionally has appeared in these pages. It has not been used much over the years, but I encourage all readers to submit such notes whenever you need to communicate a short message to the community. Examples of three such news notes are included in the present issue. Finally, let me take the occasion to remind you all to please send me updates to the mailing list when you change e-mail address.

## *Abstracts of recently accepted papers*

### **ISOCAM-CVF Spectroscopy of the Circumstellar Environment of Young Stellar Objects**

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We present the results of a mid-infrared (5–16.5 $\mu$ m) imaging spectroscopy survey of Young Stellar Objects (YSOs) and their surrounding environment in four low-mass star formation regions: RCrA,  $\rho$  Ophiuchi, Serpens and Chamaeleon I. This survey was performed using ISOCAM and its Circular Variable Filters (CVF) and observed 42 YSO candidates: we were able to obtain complete 5–16.5 $\mu$ m spectra for 40 of these with a spectral resolving power of  $\lambda/\Delta\lambda \simeq 40$ . A number of spectral features were measured, most notably the 9.7 $\mu$ m silicate feature, the bending modes of both water and CO<sub>2</sub> ices at 6.0 and 15.2 $\mu$ m respectively and the well-known unidentified feature at 6.8 $\mu$ m. The strength of the unidentified feature was observed to correlate very well with that of the water ice bending mode and far less strongly with the CO<sub>2</sub> ice bending mode. This suggests, in a manner consistent with previous observations, that the carrier of the unidentified feature is a strongly polar ice. Absorption profiles of the bending mode of CO<sub>2</sub> ice are observed to show a significant long wavelength wing, which suggests that a significant fraction of the CO<sub>2</sub> ice observed exists in

a polar (H<sub>2</sub>O-rich) phase. The sources observed in RCrA,  $\rho$  Oph and Serpens show similar spectral characteristics, whilst the sources observed in Cha I are somewhat anomalous, predominantly showing silicate emission and little or no absorption due to volatile ices. However this is consistent with previous studies of this region of the Cha I cloud, which contains an unusual cluster of YSOs. From comparisons of the strengths of the water ice and silicate bands we detect an apparent under-abundance of water ice towards the sources in  $\rho$  Oph, relative to both RCrA and Serpens. This may be indicative of differences in chemical composition between the different clouds, or may be due to evaporation. Finally the CO<sub>2</sub>:H<sub>2</sub>O ice ratios observed towards the sources in  $\rho$  Oph show significantly greater scatter than in the other regions, possibly due to varying local conditions around the YSOs in  $\rho$  Oph.

Accepted by Astronomy & Astrophysics

Preprint available at <http://xxx.lanl.gov/abs/astro-ph/0302178>.

## The line-of-sight distribution of water in the SgrB2 complex

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We report the detection, with the Caltech Submillimeter Observatory, of the 894-GHz HDO(1<sub>1,1</sub> – 0<sub>0,0</sub>) transition, observed in absorption against the background continuum emission of the SgrB2 cores M and N. Radiative transfer modeling of this feature, together with the published data set of mm and submm HDO and H<sub>2</sub><sup>18</sup>O transitions, suggests that ground-state absorption features from deuterated and non-deuterated water trace different gas components along the line of sight. In particular, while the HDO line seems to be produced by the large column densities of gas located in the SgrB2 warm envelope, the H<sub>2</sub><sup>18</sup>O ground-state transition detected by SWAS and KAO at 548 GHz (Neufeld et al. 2000; Zmuidzinas et al. 1995) is instead a product of the hot, diffuse, thin gas layer lying in the foreground of the SgrB2 complex.

Accepted by Astronomy & Astrophysics

<http://arxiv.org/abs/astro-ph/0303004>

## Intrinsic Properties of the Young Stellar Object SU Aurigae

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In this study intensive long-term photometric observations of the archetypical young G2 IIIe stellar object SU Aurigae are analyzed to determine many of its photometric and physical properties. Combining nearly 2000 Strömgren *uvby* measures obtained using the 0.8m Four College Automatic Photoelectric Telescope, previously published photometry, and recently obtained high resolution echelle spectra has led to the determination of its effective temperature, surface gravity, luminosity, mass, age, rotation period, and absolute radius. Since the disk of SU Aur is seen at a high inclination angle (*i.e.* nearly edge-on), this complicates the observations with significant ( $\Delta V \approx \Delta y < \approx 0.80$  mag), and apparently random, drops in observed mean light. These are possibly due to the transits of protoplanetary bodies, protocomets, or associated accretion halos. In this study, an effort has been made to separate the contributions of the circumstellar disk from the intrinsic properties of the stellar core itself. Furthermore, photometry has been simultaneously obtained for the nearby young A0 Vpe stellar companion AB Aurigae. Analysis has shown that SU Aur and AB Aur are a coeval proper motion pair. Also included are certain photometric and physical properties of AB Aur.

Accepted by The Astrophysical Journal

# An XMM-Newton-based X-ray survey of pre-main sequence stellar emission in the L1551 star-forming complex

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We present a study of the X-ray sources present in the nearby L1551 star forming region, based on a deep XMM-Newton observation complemented with *Chandra* data for the brightest sources. All the known pre-main sequence stars in the region have been detected, most of them with sufficient statistics to allow a detailed study of the temporal and spectral characteristics of their X-ray emission. Significant temporal (and spectral) variability on both short and long time scales is visible for most of the stars. In particular XZ Tau shows large-amplitude variations on time scales of several hours with large changes in the intervening absorption, suggestive of the X-ray emission being eclipsed by the accretion stream (and thus of the X-ray emission being partly or totally accretion-induced). The coronal metal abundance of the WTTS sources is clustered around  $Z \simeq 0.2$ , while the CTTS sources span almost two orders of magnitudes in coronal  $Z$ , even though the photospheric abundance of all stars in the L1551 is likely to be very similar. Some individual elements (notably Ne) appear to be systematically enhanced with respect to Fe in the WTTS stars. The significant differences between the spectral and temporal characteristics of the CTTS and WTTS populations suggest that a different emission mechanism is (at least partly) responsible for the X-ray emission of the two types of stars.

Accepted by Astronomy & Astrophysics

<ftp://astro.esa.int/pub/ffavata/Papers/h4098.pdf>

## On the source of dense outflows from T Tauri stars. I. Photoionization of cool MHD disk winds.

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Cool MHD disk wind physics is reviewed by means of a self-similar analytical model, making special emphasis on the mathematical aspects of the solution. It is found that the key parameter of the theory ( $\mu$ ) measures the relation between magnetic and tidal forces. The generation of MHD winds from accretion disks requires a subtle tuning between both stresses since only a narrow range of  $\mu$  values is allowed; this range is, indeed, close to the cut-off of the magnetic turbulence induced by the development of the Balbus-Hawley instability. The space of solutions can be separated into two quite distinct classes: *Low- $\mu$  solutions* generate magnetically dominated outflows and display a characteristic density change from horizontal to vertical stratification while in *high- $\mu$  solutions* the density falls down without any intermediate enhancement as one approaches the rotation axis.

These theoretical (dynamical) results have been used to study the properties of the base of the wind. Density and velocity laws have been derived directly from the dynamics. The effect of the propagation of the stellar X-rays radiation through the wind has been analyzed to determine the temperature law at the base of the wind (polar angles  $\theta > 45^\circ$ ). It is shown that a cocoon of photoionized gas is generated around the star. The extent of the photoionized region is small (tenths of AU) in dense outflows and close to the disk plane however, it may cover the whole wind extent in diffuse winds, *e.g.*, disk winds generated by small accretion rates ( $\leq 10^{-9} M_\odot \text{yr}^{-1}$ ). Photoionization also modifies the electron density in the plasma, as a consequence, the ambipolar diffusion heating decreases in the inner part of the wind by roughly one order of magnitude with respect to that derived by García et al (2001). In fact, radiative heating controls the thermal properties of the inner 0.3 AU and 1 AU of the disk wind for accretion rates of  $10^{-7} M_\odot \text{yr}^{-1}$  and  $10^{-8} M_\odot \text{yr}^{-1}$ , respectively.

The temperature of the densest region (base) of the wind is, at most,  $\simeq 10,000$  K. Therefore, although densities as high as  $\sim 10^9 \text{ cm}^{-3}$  can be achieved by disk winds, the temperature is significantly smaller than the  $\sim 5 \times 10^5 - 8 \times 10^5$  K derived from the ultraviolet observations of the base of the optical jets. Also, it is shown that densities as high as  $\sim 10^9 \text{ cm}^{-3}$  cannot be achieved at the jet recollimation point for the accretion rates observed in the T Tauri stars. In summary, we conclude that the flow traced by the UV semiforbidden lines is not associated with cold disk winds but, most likely, it is tracing the hot inner jet, postulated in cold disk wind theory, which prevents the radial collapse of the wind.

Accepted by MNRAS

## Time evolution of X-ray coronal activity in PMS stars; a possible relation with the evolution of accretion disks

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We investigate the evolution of X-ray stellar activity from the age of the youngest known star forming regions (SFR),  $< 1$  Myr, to about 100 Myr, i.e. the zero age main sequence (ZAMS) for a  $\sim 1M_{\odot}$  star. We consider five SFR of varying age ( $\rho$  Ophiuchi, the Orion Nebula Cluster, NGC 2264, Chamaeleon I, and  $\eta$  Chamaeleontis) and two young clusters (the Pleiades and NGC 2516). Optical and X-ray data for these regions are retrieved both from archival observations and recent literature, and reanalyzed here in a consistent manner so to minimize systematic differences in the results.

We study trends of  $L_X$  and  $L_X/L_{\text{bol}}$  as a function of stellar mass and association age. For low mass stars ( $M < 1M_{\odot}$ ) we observe an increase in  $L_X/L_{\text{bol}}$  in the first 3-4 Myr and a subsequent leveling off at the *saturation* level ( $L_X/L_{\text{bol}} \sim -3$ ). Slowly evolving very low mass stars then retain saturated levels down to the oldest ages here considered, while for higher mass stars activity begins to decline at some age after  $\sim 10^7$  years.

We find our data consistent with the following tentative picture: low mass PMS stars with no circumstellar accretion disk have saturated activity, *consistently* with the activity-Rossby number relation derived for MS stars. Accretion and/or the presence of disks somehow lowers the observed activity levels; disk dissipation and/or the decrease of mass accretion rate in the first few Myrs of PMS evolution is therefore responsible for the observed increase of  $L_X/L_{\text{bol}}$  with time.

Accepted by A&A

For preprints via WWW: <http://www.astropa.unipa.it/Library/preprint.html>

## Periodic flares in the methanol maser source G9.62+0.20E

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The class II methanol maser source G9.62+0.20E has been monitored since 1999 at 6.7 GHz and since 2000 at 12.2 GHz. Six flares have been observed to date. These flares are periodic, with an interval of 246 days between flares. The duration of the flare is approximately three months, with maximum amplitude reached a month after the start of the flare.

Accepted for MNRAS Letters

## Dust emission from young outflows: the case of L 1157

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We present new high-sensitivity 1.3 mm bolometer observations of the young outflow L 1157. These data show that the continuum emission arises from *four* distinct components: a circumstellar disk, a protostellar envelope, an extended flattened envelope –the dense remnant of the molecular cloud in which the protostar was formed–, and the outflow itself, which represents  $\sim 20\%$  of the total flux. The outflow emission exhibits two peaks that are coincident with the two strong shocks in the southern lobe of L 1157. We show that the mm continuum is dominated by thermal dust emission arising in the high velocity material. The spectral index derived from the new 1.3 mm data and 850  $\mu\text{m}$  observations from Shirley et al. (2000), is  $\sim 5$  in the outflow, significantly higher than in the protostellar envelope ( $\sim 3.5$ ). This can be explained by an important line contamination of the 850  $\mu\text{m}$  map, and/or by different dust characteristics in the two regions, possibly smaller grains in the post-shocks regions of the outflow. Our observations show that bipolar outflows can present compact emission peaks which must not be misinterpreted as protostellar condensations when mapping star forming regions.

Accepted by Astronomy & Astrophysics Letters

Preprint available at <http://arXiv.org/abs/astro-ph/0302477>

## 18-cm VLA observations of OH towards the Galactic Centre. Absorption and emission in the four ground-state OH lines

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The OH distribution in the Sgr A Complex has been observed in the 1612-, 1665-, 1667- and 1720-MHz OH transitions with the Very Large Array (VLA) in BnA configuration. Maps are presented with a channel velocity resolution of about  $9 \text{ km s}^{-1}$  and with angular resolutions of  $4'' \times 3''$ . Some clear results are highlighted here, such as absorption from the Circumnuclear Disk (CND) and the OH-Streamer inside the CND near Sgr A\*, strong absorption towards most of the eastern and western parts of the Sgr A East shell, lack of absorption towards both Sgr A West and the compact HII-regions to the east of Sgr A East, and double-lobed structure of the High Negative Velocity Gas (HNVG) oriented northeast and southwest of Sgr A\*, and finally compact, point-like maser emission in all four transitions, in particular a 1720-MHz maser at  $-132 \text{ km s}^{-1}$  in the CND as counterpart to a 1720-MHz maser at  $+132 \text{ km s}^{-1}$  in the CND.

Accepted by A&A

## Diffusion in supersonic, turbulent, compressible flows

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We investigate diffusion in supersonic, turbulent, compressible flows. Supersonic turbulence can be characterized as network of interacting shocks. We consider flows with different rms Mach numbers and where energy necessary to maintain dynamical equilibrium is inserted at different spatial scales. We find that turbulent transport exhibits super-diffusive behavior due to induced bulk motions. In a comoving reference frame, however, diffusion behaves normal and can be described by mixing length theory extended into the supersonic regime. Our results will help to understand chemical mixing in the ISM, the abundance distribution observed in young star clusters, and they can be used to constrain models of interstellar turbulence.

Accepted for publication in Phys. Rev. E

Preprints are available in low resolution at [astro-ph/0302527](http://astro-ph/0302527), and in high resolution at <http://www.aip.de/~ralf/Publications/p21.abstract.html>

## First NH<sub>3</sub> detection of the Orion Bar

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Odin has successfully observed three regions in the Orion A cloud, i.e. Ori KL, Ori S and the Orion Bar, in the 572.5 GHz rotational ground state line of ammonia, ortho-NH<sub>3</sub> ( $J, K$ ) = (1, 0) → (0, 0), and the result for the Orion Bar represents the first detection in an ammonia line. Several velocity components are present in the data. Specifically, the observed line profile from the Orion Bar can be decomposed into two components, which are in agreement with observations in high- $J$  CO lines by Wilson et al. 2001. Using the source model for the Orion Bar by these authors, our Odin observation implies a total ammonia abundance of NH<sub>3</sub>/H<sub>2</sub> = 5 × 10<sup>-9</sup>.

Accepted by A&A

Preprints at: <http://arxiv.org/abs/astro-ph/0303122>

## Centimetre continuum emission from young stellar objects in Cederblad 110

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The low-mass star formation region associated with the reflection nebula Cederblad 110 in the Chamaeleon I cloud was mapped with the Australian Telescope Compact Array (ATCA) at 6 and 3.5 cm. Altogether 11 sources were detected, three of which are previously known low mass young stellar objects associated with the nebula: the illuminating star IRS 2 (Class III, *Einstein* X-ray source CHX 7), the brightest far-infrared source IRS 4 (Class I), and the weak X-ray source CHX10a (Class III). The other young stellar objects in the region, including the Class 0 protostar candidate Cha-MMS1, were not detected. The radio spectral index of IRS 4 ( $\alpha = 1.7 \pm 0.3$ ) is consistent with optically thick free-free emission arising from a dense ionized region, probably a jet-induced shock occurring in the circumstellar material. As the only Class I protostar with a 'thermal jet' IRS 4 is the strongest candidate for the central source of the molecular outflow found previously in the region. The emission from IRS 2 has a flat spectrum ( $\alpha = 0.05 \pm 0.05$ ) but shows no sign of polarization, and therefore its origin is likely to be optically thin free-free emission either from ionized wind or a collimated jet. The strongest source detected in this survey is a new compact object with a steep negative spectral index ( $-1.1$ ) and a weak linear polarization ( $\sim 2\%$ ), which probably represents a background radio galaxy.

Accepted by A&A

<http://arXiv.org/abs/astro-ph/0302415>

## The 1.2 mm image of the $\beta$ Pictoris disk

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We present millimeter imaging observations in the 1200  $\mu\text{m}$  continuum of the disk around  $\beta$  Pic. With the 25'' beam, the  $\beta$  Pic disk is unresolved perpendicularly to the disk plane ( $\leq 10''$ ), but slightly resolved in the northeast-southwest direction (26''). Peak emission is observed at the stellar position. A secondary maximum is found 1000 AU along the disk plane in the southwest, which does not positionally coincide with a similar feature reported earlier at 850  $\mu\text{m}$ . Arguments are presented which could be seen in support of the reality of these features. The observed submm/mm emission is consistent with thermal emission from dust grains, which are significantly larger than those generally found in the interstellar medium, including mm-size particles, and thus more reminiscent of the dust observed in protostellar disks. Modelling the observed scattered light in the visible and the emission in the submm/mm provides evidence for the particles dominating the scattering in the visible/NIR and those primarily responsible for the thermal emission at longer wavelengths belonging to different populations.

Accepted by Astron. Astrophys.

<http://xxx.lanl.gov/abs/astro-ph/0302488>

## First detection of $\text{NH}_3$ ( $1_0 \rightarrow 0_0$ ) from a low mass cloud core: On the low ammonia abundance of the $\rho$ Oph A core

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Odin has successfully observed the molecular core  $\rho$  Oph A in the 572.5 GHz rotational ground state line of ammonia,  $\text{NH}_3$  ( $J_K = 1_0 \rightarrow 0_0$ ). The interpretation of this result makes use of complementary molecular line data obtained

from the ground ( $C^{17}O$  and  $CH_3OH$ ) as part of the Odin preparatory work. Comparison of these observations with theoretical model calculations of line excitation and transfer yields a quite ordinary abundance of methanol,  $X(CH_3OH) = 3 \times 10^{-9}$ . Unless  $NH_3$  is not entirely segregated from  $C^{17}O$  and  $CH_3OH$ , ammonia is found to be significantly underabundant with respect to typical dense core values, viz.  $X(NH_3) = 8 \times 10^{-10}$ .

Accepted by Astron. Astrophys. Letters

<http://xxx.lanl.gov/abs/astro-ph/0303132>

## Ejection of a Low Mass Star in a Young Stellar System in Taurus

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We present the analysis of high angular resolution VLA radio observations, made at eleven epochs over the last 20 years, of the multiple system T Tauri. One of the sources (Sb) in the system has moved at moderate speed (5-10 km  $s^{-1}$ ), on an apparently elliptical orbit during the first 15 years of observations, but after a close ( $< 2$  AU) encounter with the source Sa, it appears to have accelerated westward to about 20 km  $s^{-1}$  in the last few years. Such a dramatic orbital change most probably indicates that Sb has just suffered an ejection – which would be the first such event ever detected. Whether Sb will ultimately stay on a highly elliptical bound orbit, or whether it will leave the system altogether will be known with about five more years of observations.

Accepted by The Astrophysical Journal (Letters)

<http://www.astrosmo.unam.mx/~l.loinard/publi.html>

## Polarimetric variations of binary stars. V. Pre-main-sequence spectroscopic binaries located in Ophiuchus and Scorpius

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We present polarimetric observations of 7 pre-main-sequence (PMS) spectroscopic binaries located in the  $\rho$  Ophiuchus and Upper Scorpius star forming regions (SFRs). The average observed polarizations at 7660Å are between 0.5% and 3.5%. After estimates of the interstellar polarization are removed, all binaries have an *intrinsic* polarization above 0.4%, even though most of them do not present other evidences for circumstellar dust. Two binaries, NTTS 162814-2427 and NTTS 162819-2423S, present high levels of intrinsic polarization between 1.5% and 2.1%, in agreement with the fact that other observations (photometry, spectroscopy) indicate the presence of circumstellar dust. Tests reveal that all 7 PMS binaries have a statistically variable or possibly variable polarization. Combining these results with our previous sample of binaries located in the Taurus, Auriga and Orion SFRs, 68% of the binaries have an intrinsic polarization above 0.5%, and 90% of the binaries are polarimetrically variable or possibly variable. NTTS 160814-1857, NTTS 162814-2427, and NTTS 162819-2423S are clearly polarimetrically variable. The first two also exhibit phase-locked variations over  $\sim 10$  and  $\sim 40$  orbits respectively. Statistically, NTTS 160905-1859 is possibly variable, but it shows periodic variations not detected by the statistical tests; those variations are not phased-locked and only present for short intervals of time. The amplitudes of the variations reach a few tenths of a percent, greater than for the previously studied PMS binaries located in the Taurus, Orion, and Auriga SFRs. The high-eccentricity system NTTS 162814-2427 shows single-periodic variations, in agreement with our previous numerical simulations. We compare the observations with some of our numerical simulations, and also show that an analysis of the periodic polarimetric variations with the Brown, McLean, & Emslie (1978) formalism to find the orbital inclination is for the moment premature: non-periodic events introduce stochastic noise that partially masks the periodic variations and prevents the BME formalism from finding a reasonable estimate of the inclination.

Accepted by Astron. J.

<http://arXiv.org/abs/astro-ph/0302499>

# Gas in the Terrestrial Planet Region of Disks: CO Fundamental Emission from T Tauri Stars

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We report the results of a high resolution spectroscopic survey for CO fundamental emission from T Tauri stars. CO fundamental emission is frequently detected, with the likely origin of the emission in the circumstellar disk. An initial assessment of the line profiles indicates that the emission region includes the equivalent of the terrestrial planet region of our Solar System, a result which suggests the utility of CO fundamental emission as a probe of disks at planet formation distances. Since fundamental emission is detected frequently from both close binary and apparently single stars, it appears that both low column density regions, such as disk gaps, and temperature inversion regions in disk atmospheres can produce significant emission. The estimated excitation temperature of the emitting gas is unexpectedly warm for the disk radii that they appear to probe. Thus, the surface gaseous component of inner disks may be significantly warmer than the surface dust component. We also detect CO emission from a transitional T Tauri star. Because fundamental emission from CO and its isotopes is sensitive to a wide range of gas masses, including masses  $\ll M_{\oplus}$ , CO fundamental emission may prove useful in measuring the residual gas content of dissipating disks. This may be an effective way to explore the gas dissipation timescale in inner disks, and to thereby place constraints on the timescale for giant planet formation.

Accepted by The Astrophysical Journal

A preprint is available at the ApJ website: <http://www.journals.uchicago.edu/ApJ/future.html>

## Low Upper Limits on the O<sub>2</sub> Abundance from the Odin Satellite

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For the first time, a search has been conducted in our Galaxy for the 119 GHz transition connecting to the ground state of O<sub>2</sub>, using the Odin satellite. Equipped with a sensitive 3mm receiver ( $T_{\text{sys}}(\text{SSB}) = 600$  K), Odin has reached unprecedented upper limits on the abundance of O<sub>2</sub>, especially in cold dark clouds where the excited state levels involved in the 487 GHz transition are not expected to be significantly populated. Here we report upper limits for a dozen sources. In cold dark clouds we improve upon the published SWAS upper limits by more than an order of magnitude, reaching  $N(\text{O}_2)/N(\text{H}_2) \leq 10^{-7}$  in half of the sources. While standard chemical models are definitively ruled out by these new limits, our results are compatible with several recent studies that derive lower O<sub>2</sub> abundances. Goldsmith et al. (2002, ApJ, 576, 814) recently reported a SWAS tentative detection of the 487 GHz transition of O<sub>2</sub> in an outflow wing towards  $\rho$  Oph A in a combination of 7 beams covering approximately  $10' \times 14'$ . In a brief (1.3 hour integration time) and partial covering of the SWAS region ( $\approx 65\%$  if we exclude their central position), we did not detect the corresponding 119 GHz line. Our 3 sigma upper limit on the O<sub>2</sub> column density is  $7.3 \cdot 10^{15} \text{ cm}^{-2}$ . We presently cannot exclude the possibility that the SWAS signal lies mostly outside of the 9 arcmin Odin beam and has escaped our sensitive detector.

Accepted by A&A

<http://aramis.obspm.fr/~pagani/O2.Odin.ps>

## The Thermal Regulation of Gravitational Instabilities in Protoplanetary Disks

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We present a series of high-resolution, three-dimensional hydrodynamics simulations of a gravitationally unstable Solar Nebula model. The influences of both azimuthal grid resolution and the treatment of thermal processes on the origin and evolution of gravitational instabilities are investigated. In the first set of simulations, we vary the azimuthal resolution for a locally isothermal simulation, doubling and quadrupling the resolution used in a previous study; the largest number of gridpoints is (256,256,64) in cylindrical coordinates  $(r, \varphi, z)$ . At this resolution, the disk breaks apart into a dozen, short-lived condensations. Although our previous calculations under-resolved the number and growth rate of clumps in the disk, the overall qualitative, but fundamental, conclusion remains: fragmentation under the locally isothermal condition in numerical simulations does not in itself lead to the survival of clumps to become gaseous giant protoplanets.

Since local isothermality represents an extreme assumption about thermal processes in the disk, we also present several extended simulations in which heating from an artificial viscosity scheme and cooling from a simple volumetric cooling function are applied to two different models of the Solar Nebula. The models are differentiated primarily by disk temperature: a High- $Q$  Model generated directly by our self-consistent field equilibrium code and a Low- $Q$  Model generated by cooling the High- $Q$  Model in a 2-D version of our hydrodynamics code. Here, “High- $Q$ ” and “Low- $Q$ ” refer to the minimum values of the Toomre stability parameter  $Q$  in each disk,  $Q_{min} = 1.8$  and 0.9, respectively. Previous simulations, by ourselves as well as others, have focused on initial states that are already gravitationally unstable, i.e., models similar to the Low- $Q$  model. This paper presents for the first time the numerical evolution of an essentially stable initial equilibrium state (the High- $Q$  model) to a severely unstable one by cooling.

The additional heating and cooling are applied to each model over the outer half of the disk or the entire disk. The models are subject to the rapid growth of a four-armed spiral instability; the subsequent evolution of the models depends on the thermal behavior of the disk. The cooling function tends to overwhelm the heating included in our artificial viscosity prescription, and as a result the spiral structure strengthens. The spiral disturbances transport mass at prodigious rates during the early nonlinear stages of development and significantly alter the disk’s vertical surface. Although dense condensations of material can appear, their character depends on the extent of the volumetric cooling in the disk. In the simulation of the High- $Q$  Model with heating and cooling applied throughout the disk, thin, dense rings form at radii ranging from 1 to 3 AU and steadily increase in mass; later companion formation may occur in these rings as cooling drives them towards instability. When heating and cooling are applied only over the outer radial half of the disk, however, a succession of single condensations appears near 5 AU. Each clump has roughly the mass of Saturn, and some survive a complete orbit. Since the clumps form near the artificial boundary in the treatment of the disk gas physics, the production of a clump in this case is a numerical artifact. Nevertheless, radially abrupt transitions in disk gas characteristics, for example in opacity, might mimic the artificial boundary effects in our simulations and favor the production of stable companions in actual protostellar and protoplanetary disks. The ultimate survival of condensations as eventual stellar or substellar companions to the central star is still largely an open question.

Accepted by the Astrophysical Journal

## Adaptive Optics Spectroscopy of the [Fe II] Outflows from DG Tauri

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We present results of the velocity-resolved spectroscopy of the [Fe II]  $\lambda 1.644 \mu\text{m}$  emission line along the optical jet emanating from DG Tau. The slit spectrum, obtained with the Subaru Telescope Adaptive Optics System at an angular resolution of  $0''.16$ , shows strong, entirely blueshifted emission on the southwestern side of the star. A faint, redshifted counter feature was also detected on the northeast side with emission within  $0''.7$  of the star being occulted by the circumstellar disk. The blueshifted emission has two distinct radial velocity components. The low-velocity component (LVC) has a peak radial velocity of  $\sim -100 \text{ km s}^{-1}$  with an FWHM line width of  $\sim 100 \text{ km s}^{-1}$ , and it peaks at  $0''.2$ – $0''.5$  from the star. The high-velocity component (HVC) peaks at  $0''.6$ – $0''.8$  away from the star, showing a peak radial velocity of  $\sim -220 \text{ km s}^{-1}$  with a line width of  $\sim 50 \text{ km s}^{-1}$ . These characteristics are remarkably similar to the [Fe II] outflow from L1551 IRS 5, although the linear scales of the HVCs and LVCs are different for the two objects. We conclude, as an analogy to the case of L1551 IRS 5, that the HVC is a well-collimated jet launched from the region close to the star and the LVC is a disk wind with a wide opening angle. Detailed comparison of emission parameters between the two sources, however, suggests that part of the LVC emission from DG Tau arises from the gas entrained and accelerated by the HVC, if we assume continuous steady-state outflows. The presence of two distinct emission components clearly separated in space and velocity may favor theoretical models with two outflows: one is the LVC magnetohydrodynamically driven near the inner edge of an accretion disk, and the other is the HVC driven by the reconnection of dipolar stellar magnetic fields anchored to the disk.

Accepted by *Astrophys. J.*

Preprint at <http://www.naoj.org/staff/pyo/DGTau.pdf>

## Constraints on a planetary origin for the gap in GM Aurigae’s protoplanetary disc

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The unusual spectral energy distribution (SED) of the classical T Tauri star GM Aurigae provides evidence for the presence of an inner disc hole extending to several au. Using a combination of hydrodynamical simulations and Monte Carlo radiative transport, we investigate whether the observed SED is consistent with the inner hole being created and maintained by an orbiting planet. We show that an  $\sim 2M_{\text{Jupiter}}$  planet, orbiting at 2.5 au in a disc with mass  $0.047M_{\odot}$  and radius 300 au, provides a good match both to the SED and to CO observations which constrain the velocity field in the disc. A range of planet masses is allowed by current data, but could in principle be distinguished with further observations between 3 and  $\sim 20$  microns. Future high precision astrometric instruments should also be able to detect the motion of the central star due to an orbiting Jupiter mass planet. We argue that the small number of T Tauri stars with SEDs resembling that of GM Aur is broadly consistent with the expected statistics of embedded migrating planets.

Accepted by *MNRAS*

<http://star-www.st-and.ac.uk/astronomy/Welcome>

## The Binary Jet in L1551 IRS5

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We have used the Very Large Array with the Pie Town antenna of the Very Long Baseline Array to image for the

first time L1551 IRS5 at 3.5 cm with an angular resolution of  $\sim 0''.1$ . These observations clearly reveal the presence of a binary jet, with each component approximately centered on the 7 mm compact protoplanetary disks previously reported. As anticipated from results at various wavelengths, L1551 IRS5 is a binary system where each star is surrounded by a disk and drives a collimated jet. The curved morphology of the northern jet, showing reflection symmetry, is suggestive of that expected for a source in a binary orbit. A region of radio emission located between the two jets could be a zone of shock interaction between the two outflows.

Accepted by The Astrophysical Journal (Letters)

<http://www.astrosmo.unam.mx/~luisfr/publ.html>

## Odin observations of H<sub>2</sub>O in the Galactic Centre

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The Odin satellite has been used to detect emission and absorption in the 557-GHz H<sub>2</sub><sup>16</sup>O line in the Galactic Centre towards the Sgr A\* Circumnuclear Disk (CND), and the Sgr A +20 km s<sup>-1</sup> and +50 km s<sup>-1</sup> molecular clouds. Strong broad H<sub>2</sub>O emission lines have been detected in all three objects. Narrow H<sub>2</sub>O absorption lines are present at all three positions and originate along the lines of sight in the 3-kpc Spiral Arm, the -30 km s<sup>-1</sup> Spiral Arm and the Local Sgr Spiral Arm. Broad H<sub>2</sub>O absorption lines near -130 km s<sup>-1</sup> are also observed, originating in the Expanding Molecular Ring. A new molecular feature (the "High Positive Velocity Gas" - HPVG) has been identified in the positive velocity range of  $\approx +120$  to  $+220$  km s<sup>-1</sup>, seen definitely in absorption against the stronger dust continuum emission from the +20 km s<sup>-1</sup> and +50 km s<sup>-1</sup> clouds and possibly in emission towards the position of Sgr A\* CND. The 548-GHz H<sub>2</sub><sup>18</sup>O isotope line towards the CND is not detected at the 0.02 K (rms) level.

Accepted by A&A

## The Spatial Distribution of Fluorescent H<sub>2</sub> Emission Near T Tau

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New subarcsecond FUV observations of T Tau with HST/STIS show spatially resolved structures in the  $2'' \times 2''$  area around the star. The structures show in multiline emission of fluorescent  $H_2$  pumped by Lyman  $\alpha$ . One emission structure follows the cavity walls observed around T Tau N in scattered light in the optical. A temperature of  $\geq 1000K$  is required to have enough population in the  $H_2$  to produce the observed fluorescent lines; in the cool environment of the T Tau system, shock heating is required to achieve this temperature at distances of a few tens of AU. Fluorescent  $H_2$  along the cavity wall represents the best evidence to date for the action of low-density, wide-opening-angle outflows driving cavities into the molecular medium at scales  $\leq 100$  AU. A southern region of emission consists of two arcs, with shape and orientation similar to the arcs of  $H_2$  2.12  $\mu m$  and forbidden line emission crossing the outflow associated with the embedded system T Tau S. This region is located near the centroid of forbidden line emission at the blueshifted lobe of the N-S outflow.

Accepted by ApJ

Preprint available at <http://cfa-www.harvard.edu/cfa/youngstars/>

## Orbital motion of the massive multiple stars in the Orion Trapezium

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We present bispectrum speckle interferometry of the multiple Orion Trapezium stars  $\theta^1$ Ori A,  $\theta^1$ Ori B, and  $\theta^1$ Ori C obtained with the SAO 6m telescope in Russia over a period of 5.5 years (epochs 1995 – 2001). Our diffraction-limited images have a resolution  $\lambda/D$  of 42 mas ( $J$ -band), 57 mas ( $H$ -band) and 76 mas ( $K$ -band). We clearly detect motion of the companions relative to their primary stars in the systems  $\theta^1$ Ori A1–2 (mean separation  $\rho \sim 220$  mas, change in position angle  $\Delta P.A. = 6$  deg),  $\theta^1$ Ori B2–3 ( $\rho \sim 205$  mas,  $\Delta P.A. = 8$  deg), and  $\theta^1$ Ori C1–2 ( $\rho \sim 37$  mas,  $\Delta P.A. = 18$  deg). In our  $K$ -band image of  $\theta^1$ Ori B we resolve a fourth visual component, confirming its discovery by Simon et al. (1999). We determine the  $J$ ,  $H$ , and  $K$  magnitudes of the system components and estimate the stellar masses of the companions in the HR-diagram. The companions  $\theta^1$ Ori C2 and  $\theta^1$ Ori B2 show clear evidence of near-infrared excess in the color-color diagram. The companions  $\theta^1$ Ori A2 and  $\theta^1$ Ori B3 show much stronger extinction than their primary stars, providing evidence of the presence of circumstellar material around the companions.

Accepted by Astronomy & Astrophysics

Preprints are available at <http://www.mpifr-bonn.mpg.de/div/ir-interferometry/publications.html>

## Molecular radio emission from the G34.26+0.15/34.24+0.13 complex

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We report on molecular line observations of the G34.26+0.15/34.24+0.13 complex, which contains a bright molecular core and a proto-B star. ATCA observations show that both objects are closely associated with 6.7 GHz class II methanol masers. Methanol line series at 96 GHz, 157 GHz, and 241 GHz toward the protostar position were observed at SEST. Modelling of the methanol data shows that the molecular core embedding protostar is not greatly influenced by the outflow from the young stellar object. Molecular line mapping at Onsala reveals the presence of a cavity and 2 compact clumps to the south-east of the bright molecular core. The protostar is situated at the edge of one compact clump. It is very likely that the material outflowing from the protostar freely escapes toward the cavity. Comparison of the line profiles of different molecules shows substantial chemical inhomogeneity within the region.

Accepted by Astron. and Astrophys. Transactions

## Images of Astrophysical Masers and their Variability in a Turbulent Medium: The 25 GHz methanol masers

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The influence of the chance coherences in turbulent velocities for creating the images of astrophysical masers is examined. Images are computed that represent the numerous masing features that commonly are observed in an extended masing region. Changes as a function of Doppler velocity can be seen in the appearance of these images. Variability in the images also is evident as a result of the evolution of the turbulent velocities with time. Representative turbulent velocity fields are obtained by standard methods involving the statistical sampling of Fourier components, and the medium is treated as incompressible for computing the time evolution of the turbulence. The comparisons with observational data focus on the 25 GHz methanol masers for which there is evidence that their structure may be caused mainly by coherences in the velocities.

Accepted by *Astrophys. J.*

## Deuterium fractionation on interstellar grains studied with the direct master equation approach

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We have studied deuterium fractionation on interstellar grains with the use of an exact method known as the direct master equation approach. We consider conditions pertinent to dense clouds at late times when the hydrogen is mostly in molecular form and a large portion of the gas-phase carbon has already been converted to carbon monoxide. Hydrogen, oxygen, and deuterium atoms, as well as CO molecules, are allowed to accrete onto dust particles and react there to produce various stable molecules. The surface abundances, as well as the abundance ratios between deuterated and normal isotopomers, are compared with those calculated with the Monte Carlo approach. We find that the agreement between the Monte Carlo and the direct master equation methods can be made as close as desired. Compared with previous examples of the use of the direct master equation approach, our present method is much more efficient. It should now be possible to run large-scale gas-grain models in which the diffusive dust chemistry is handled “exactly”.

Accepted by *Mon. Not. R. Astron. Soc.*

## Submillimeter Emission from Water in the W3 Region

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Using the Odin satellite, we have mapped the submillimeter emission from the  $1_{10} - 1_{01}$  transition of *ortho*-water in the W3 star-forming region. A  $5\text{arcmin} \times 5\text{arcmin}$  map of the W3 IRS4 and W3 IRS5 region reveals strong water lines at half the positions in the map. The relative strength of the Odin lines compared to previous observations by SWAS suggests that we are seeing water emission from an extended region. Across much of the map the lines are double-peaked, with an absorption feature at  $-39\text{ km s}^{-1}$ ; however, some positions in the map show a single strong line at  $-43\text{ km s}^{-1}$ . We interpret the double-peaked lines as arising from optically thick, self-absorbed water emission near the W3 IRS5, while the narrower blue-shifted lines originate in emission near W3 IRS4. In this model, the unusual appearance of the spectral lines across the map results from a coincidental agreement in velocity between the emission near W3 IRS4 and the blue peak of the more complex lines near W3 IRS5. The strength of the water lines near W3 IRS4 suggests we may be seeing water emission enhanced in a photon-dominated region.

Accepted by A&A Letters, special Odin edition

## SCUBA Observations of Dust around Lindroos Stars: Evidence for a Submillimetre Disc Population

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We have observed 22 young stars from the Lindroos sample (Lindroos 1986) at  $850\ \mu\text{m}$  with SCUBA on the JCMT to search for evidence of dust discs. Stars in this sample are the less massive companions of B-type primaries and have well defined ages that are 10 – 170 Myr; i.e., they are about to, or have recently arrived on the main sequence. Dust was detected around three of these stars (HD74067, HD112412 and HD99803B). The emission around HD74067 is centrally peaked and is approximately symmetrically distributed out to  $\sim 70\text{ arcsec}$  from the star. This emission either arises from a two component disc, one circumstellar and the other circumbinary with dust masses of  $0.3$  and  $> 27M_{\oplus}$  respectively, or an unrelated background object. The other two detections we attribute to circumsecondary discs with masses of  $0.04$  and  $0.3 M_{\oplus}$ ; we were also able to show that a circumprimary disc is present around HD112413 with a similar mass to that around the companion HD112412. Cross-correlation of our sample with the *IRAS* catalogs only showed evidence for dust emission at  $25\ \mu\text{m}$  and  $60\ \mu\text{m}$  toward one star (HD1438); none of the sub-mm detections were evident in the far-IR data implying that these discs are cold ( $< 40\text{ K}$  assuming  $\beta = 1$ ). Our sub-mm detections are some of the first of dust discs surrounding evolved stars that were not detected by *IRAS* or *ISO* and imply that 9-14% of stars could harbour previously undetected dust discs that await discovery in unbiased sub-mm surveys. If these discs are protoplanetary remnants, rather than secondary debris discs, dust lifetime arguments show that they must be devoid of small  $< 0.1\text{ mm}$  grains. Thus it may be possible to determine the origin of these discs from their spectral energy distributions once these have been better defined. The low inferred dust masses for this sample support the picture that protoplanetary dust discs are depleted to the levels of the brightest debris discs ( $\sim 1M_{\oplus}$ ) within 10 Myr, although if the extended emission of HD74067 is associated with the star, this would indicate that  $> 10M_{\oplus}$  of circumbinary material can persist until  $\sim 60\text{ Myr}$  and would also support the theory that T Tauri discs in binary systems are replenished by circumbinary envelopes.

Accepted by MNRAS

Preprint available as astro-ph/0303114

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

## *Abstracts of recently accepted major reviews*

### **Gravitational Instabilities in Protostellar and Protoplanetary Disks**

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Self-gravity in fluid and particle systems is the primary mechanism for the creation of structure in the Universe on astronomical scales. The rapidly rotating Solar System-sized disks which orbit stars during the early phases of star and planet formation can be massive and thus susceptible to spontaneous growth of spiral distortions driven by disk self-gravity. These are called gravitational instabilities (GI's). They can be important sources of mass and angular momentum transport due to the long-range torques they generate; and, if strong enough, they may fragment the disk into bound lumps with masses in the range of gas giant planets and brown dwarfs. My research group has been using numerical 3D hydrodynamics techniques to study the growth and nonlinear behavior of GI's in disks around young stars. Our simulations have demonstrated the sensitivity of outcomes to the thermal physics of the disks and have helped to delineate conditions conducive to the formation of dense clumps. We are currently concentrating our efforts on determining how GI's affect the long-term evolution and appearance of young stellar disks, with the hope of finding characteristic GI signatures by which we may recognize their occurrence in real systems.

Accepted by Recent Research Developments in Astrophysics

<http://westworld.astro.indiana.edu/publications.html>

### **Star Formation in Turbulent Interstellar Gas**

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Understanding the star formation process is central to much of modern astrophysics. For several decades it has been thought that stellar birth is primarily controlled by the interplay between gravity and magnetostatic support, modulated by ambipolar diffusion. Recently, however, both observational and numerical work has begun to suggest that supersonic interstellar turbulence rather than magnetic fields controls star formation. Supersonic turbulence can provide support against gravitational collapse on global scales, while at the same time it produces localized density enhancements that allow for collapse on small scales. The efficiency and timescale of stellar birth in Galactic molecular clouds strongly depend on the properties of the interstellar turbulent velocity field, with slow, inefficient, isolated star formation being a hallmark of turbulent support, and fast, efficient, clustered star formation occurring in its absence.

Accepted by Reviews of Modern Astronomy, Vol. 16

(Preprint available at [astro-ph/0301381](http://astro-ph/0301381), or in high resolution at <http://www.aip.de/~ralf/Publications/r01.abstract.html>)

## *Dissertation Abstracts*

# Investigations of Class 0 sources and their outflows with ISO

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Ph.D degree awarded: January 2003

The earliest stage of the protostellar evolution (Class 0) is accompanied by powerful bipolar outflows which interact with the ambient medium through shocks. Investigations of their spectra allow to learn about the properties of the outflow and the surrounding gas. Ground-based observations of such flows are restricted to the optical and NIR. Thus, the youngest and most deeply embedded objects cannot be studied, since high extinction prevents observations in the optical and partly in the NIR. Here outflows from protostars (Cep E, L 1448) and young higher mass objects (Cep A, DR 21) in the MIR and FIR are observed using instruments aboard the Infrared Space Observatory (ISO). Additional, H- and K-band spectra were taken of the Cep E outflow at three positions. CO ( $J_{up} > 13$ ) and rotational H<sub>2</sub> transitions (0–0 S(1) lines) are detected in the ISO spectra at all of the observed positions. Forbidden atomic fine structure lines (e.g. [OI](63  $\mu$ m)) were found also. In the NIR spectra a variety of ro-vibrational H<sub>2</sub> lines is observed.

Up to now spectra of outflows from young stars are almost exclusively interpreted by planar shocks. Thereby the lowest excited lines often could not be explained. Several planar shocks with different velocities are needed to model the H<sub>2</sub> emission in the whole  $T_{ex}$  range. Here all H<sub>2</sub> and CO line fluxes are interpreted simultaneously by shock models ( $Z \propto R^s$  – in cylindrical coordinates), using continuous (C-type) and jump (J-type) shocks. The curvature leads to a distribution of shock strength, allowing to model also the less excited H<sub>2</sub> lines with  $T_{ex} < 5000$  K. Comparing the fluxes and the model predictions several properties of the outflows (shock velocity, velocity distribution) and the surrounding gas (density, atomic fraction, o/p-ratio of H<sub>2</sub>, abundances), and the predominant physics of the shocks can be constrained. C-type physics and a bow with a shape parameter of  $s = 1.4$  fit best to the data, independently of the object and position. Hence, a common mechanism for the generation of the velocity distribution in the bows, independent of the properties of the surrounding material and the outflow itself, is suggested. Obvious hints that the o/p-ratio of H<sub>2</sub> is different from the LTE value of three (esp. in the leading shocks in Cep E) are found, suggesting that a shock wave entering the first time the unaltered quiescent material that surrounds the protostar is observed. In two objects (DR 21 and Cep E), the spectrum of H<sub>2</sub> cannot be explained entirely by shocks. A part of the emission (a few percent of the 1–0 S(1) line) is caused by a fluorescent cascade.

The deeply embedded protostars are only observable at long wavelengths (larger than MIR). Six candidate Class 0 sources (Cep E, HH 211-MM, RNO 15 FIR, L 1157, L 1211, and IC 1396 W) were observed with the ISOPHOT photometer at 60, 100, 160 and 200  $\mu$ m. These are the first direct observations of the emission maximum of their SED. Therewith the temperature of the protostellar envelope can be determined much more accurately than with previous data. For a broader wavelength coverage our data is supplemented with IRAS, sub-mm and millimeter data.  $L_{bol}$  and  $T_{bol}$  of the source, the envelope size, and the sub-mm slope of the SED are derived. All sources could be identified as Class 0 objects by means of the  $L_{s\text{mm}}/L_{bol}$  ratio. The sample consists of relatively cool and partly luminous objects.

The source and outflow properties should be explainable by a unified model, describing the evolution of the source and the outflow. So far, no quantitatively sufficient observational material of Class 0 sources was available to test these models in detail. Here the luminosity of outflows from 15 verified Class 0 sources in the 1–0 S(1) line of H<sub>2</sub> is measured. The models explain the source and outflow luminosity and the properties of the protostellar envelope (mass and temperature). They also indicate a broad scatter in age and mass of our Class 0 sample. The outflow luminosity is up to now determined by statistical assumptions about the H<sub>2</sub> excitation and the extinction. With the bow shock models, presented in this work, it will be possible to determine the excitation of the gas, the extinction, and the luminosity of the outflows more accurately and individually. Thus, the free parameters (e.g. time evolution of the mass accretion rate, fraction of mass escaping through twin jets) of the unified model can be constrained better.

Thesis available at: <http://www.tls-tautenburg.de/research/frobrich/php/veroe.html>

# The Formation of Brown Dwarfs - Fundamental properties of very young objects near and below the substellar limit

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Ph.D degree awarded: January 2003

A population of twelve very young bona fide and candidate brown dwarfs in the Cha I star forming cloud (Cha H $\alpha$  1–12) was studied observationally in terms of their kinematic properties, the occurrence of multiple systems among them as well as their rotational characteristics. Based on high-resolution spectra taken with UVES at the VLT, radial and rotational velocities have been measured with high accuracy. A kinematic study of the sample showed that their radial velocity dispersion is relatively small ( $2.2 \text{ km s}^{-1}$ ). It is significantly smaller than the radial velocity dispersion of the T Tauri stars in the field ( $3.6 \text{ km s}^{-1}$ ) and slightly larger than that one of the surrounding molecular gas ( $1.2 \text{ km s}^{-1}$ ). This result indicates that the studied brown dwarfs are not ejected during their formation with velocities large than  $\sim 2 \text{ km s}^{-1}$  as proposed in recent formation scenarios. The brown dwarfs may have larger 3D velocities. However, brown dwarfs ejected during the early accretion phase in directions with a significant fraction perpendicular to the line-of-sight, would have flown out of the field a long time ago.

By means of time-resolved UVES spectra, a radial velocity survey for close companions to the targets was conducted. In addition, a direct imaging survey for wide companions was carried out with the WFPC camera on board the HST, with FORS at the VLT as well as with SofI at the NTT. With these two complementary search methods, a wide range of possible companion separations has been covered. For brown dwarf companions ( $> 13 M_{\text{Jup}}$ ) to the targets, separations  $< 3 \text{ AU}$  and between 50 and 1000 AU were covered. With more restricted separations ( $< 0.1 \text{ AU}$  and 300–1000 AU) the surveys were sensitive also to companion masses down to about  $1 M_{\text{Jup}}$ . HST images of Cha H $\alpha$  2 hint at a binary system comprised of two approximately equal-mass companions with a separation of  $\sim 30 \text{ AU}$ . No further indications for companions have been found in the images. Furthermore, the radial velocities of the targets turned out to be rather constant setting upper limits for the mass  $M_2 \sin i$  of possible companions to  $0.1 M_{\text{Jup}}$  to  $2 M_{\text{Jup}}$ . These findings hint at a rather low ( $\leq 10\%$ ) multiplicity fraction of the studied brown dwarfs.

Furthermore, a photometric monitoring campaign of the targets yielded the determination of rotational periods for Cha H $\alpha$  2, Cha H $\alpha$  3 and Cha H $\alpha$  6 in the range of 2.2 to 3.4 days. These are the first rotational periods for very young brown dwarfs and among the first for brown dwarfs at all. They are complemented by measurements of rotational velocities  $v \sin i$  from UVES spectra. The observations show that brown dwarfs at an age of 1–5 Myr display surface spots like T Tauri stars and are moderately fast rotators in contrast to rapidly rotating old brown dwarfs consistent with them being in an early contracting stage.

*Thesis-related Publications:* A&A 379, L9; A&A 384, 999

## *New Books*

# **The Physics of Interstellar Dust**

by **Endrik Krügel**

This is a massive and comprehensive book discussing in depth the nature of interstellar and circumstellar dust grains. The composition, morphology and size distribution of dust grains, their growth and destruction mechanisms, dynamical behaviour, optical properties, spectral features and basic surface reactions are all dealt with. Also discussed are the roles dust plays in star formation and the spectral appearance of protostars and dusty galactic nuclei. All the relevant physics towards understanding this vast material is presented in the book, including the necessary thermodynamics, radiative transport, optical properties, solid state physics, and statistical and quantum mechanics. As such, the book is likely to be of great value not only for active researchers, but also as a textbook for graduate students.

The book contains the following chapters:

### **1. The dielectric permeability**

1.1 Maxwell's Equations - 1.2 Waves in the dielectric medium - 1.3 The harmonic oscillator - 1.4 The harmonic oscillator and light - 1.5 Waves in a conducting medium - 1.6 Polarization through orientation

### **2. How to evaluate grain cross sections**

2.1 Defining cross sections - 2.2 The optical theorem - 2.3 Mie theory for a sphere - 2.4 Polarization and scattering - 2.5 The Kramers-Kronig relations - 2.6 Composite grains

### **3. Very small and very big particles**

3.1 Tiny spheres - 3.2 A small metallic sphere in a magnetic field - 3.3 Tiny ellipsoids - 3.4 The fields inside a dielectric particle - 3.5 very large particles

### **4. Case studies of Mie calculus**

4.1 Efficiencies of bare spheres - 4.2 Scattering by bare spheres - 4.3 Coated spheres - 4.4 Surface modes in small grains - 4.5 Efficiencies of idealized dielectrics and metals

### **5. Particle statistics**

5.1 Boltzmann statistics - 5.2 Quantum statistics - 5.3 Thermodynamics - 5.4 Blackbody radiation

### **6. The radiative transition probability**

6.1 A charged particle in an electromagnetic field - 6.2 Small perturbations - 6.3 The Einstein coefficients A and B - 6.4 Potential wells and tunneling

### **7. Structure and composition of dust**

7.1 Crystal structure - 7.2 Binding in crystals - 7.3 Reddening by interstellar grains - 7.4 Carbonaceous grains and silicate grains - 7.5 Grain sizes and optical constants

### **8. Dust radiation**

8.1 Kirchhoff's law - 8.2 The temperature of big grains - 8.3 The emission spectrum of big grains - 8.4 Calorific properties of solids - 8.5 Temperature fluctuations of very small grains - 8.6 The emission spectrum of very small grains

### **9. Dust and its environment**

9.1 Grain surfaces - 9.2 Grain charge - 9.3 Grain motion - 9.4 Grain destruction - 9.5 Grain formation

### **10. Polarization**

10.1 Efficiency of infinite cylinders - 10.2 Linear polarization through extinction - 10.3 Polarized emission - 10.4 Circular polarization

### **11. Grain alignment**

11.1 Grain rotation - 11.2 Magnetic dissipation - 11.3 Magnetic alignment - 11.4 Non-magnetic alignment

### **12. PAHs and spectral features of dust**

12.1 Thermodynamics of PAHs - 12.2 PAH emission - 12.3 Big grains and ices - 12.4 An overall dust model

### **13. Radiative transport**

13.1 Basic transfer relations - 13.2 Spherical clouds - 13.3 Passive disks - 13.4 Galactic nuclei - 13.5 Line radiation

### **14. Diffuse matter in the Milky Way**

14.1 Overview of the Milky Way - 14.2 Molecular clouds - 14.3 Clouds of atomic hydrogen - 14.4 HII regions - 14.5 Mass estimates of interstellar clouds

### **15. Stars and their formation**

15.1 Stars on and beyond the main sequence - 15.2 Clouds near gravitational equilibrium - 15.3 Gravitational collapse - 15.4 Disks

### **16. Emission from young stars**

16.1 The earliest stages of star formation - 16.2 The collapse phase - 16.3 Accretion disks - 16.4 Reflection nebulae - 16.5 Cold and warm dust in galaxies - 16.6 Starburst nuclei

ISBN 0 7503 0861 3

Hardback - published 2003 - 559 pages - Price US\$ 135.00 plus postage

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## *Short Announcements*

### **The Terrestrial Planet Finder Newsletter**

The Terrestrial Planet Finder project has started a Newsletter called *Star and Planet*, the purpose of which is to provide news of the Terrestrial Planet Finder (TPF) Project for a technical audience, i.e. scientists and engineers interested in the technical development of TPF, its science objectives, instrument design, and technology. The Newsletter is produced about every 3 months, and will be short. It can be found at

[http://planetquest.jpl.nasa.gov/Navigator/library/tpf\\_newsletters/](http://planetquest.jpl.nasa.gov/Navigator/library/tpf_newsletters/)

or you can receive it through e-mail by request to its editor, Steve Unwin, ([stephen.unwin@jpl.nasa.gov](mailto:stephen.unwin@jpl.nasa.gov)). The TPF project is discussed in more detail at

[http://planetquest.jpl.nasa.gov/TPF/tpf\\_index.html](http://planetquest.jpl.nasa.gov/TPF/tpf_index.html)

### **News from SIRTf**

Dear Colleague,

We are in the process of creating a mailing list for members of the community who are interested in receiving SIRTf news (e.g., news of data analysis and observation planning workshops, status reports, software, programmatic and technical updates). If you would like to be placed on such a list, please send an email to

[majordomo@ipac.caltech.edu](mailto:majordomo@ipac.caltech.edu)

In the first line of the body of the message put

subscribe sirtf-astro <your email address>

where <your email address> is the address where you want SIRTf announcements to be sent.

Messages to the mailing list will also be archived on the web here:

<http://sirtf.caltech.edu/SSC/ost/mlist/>

### **News from the James Clerk Maxwell Telescope**

I am in the process of updating the email list for the JCMT USERS email exploder, and if you are interested in applying for JCMT time I would like to invite you to subscribe. This list is moderated, and is used primarily for disseminating information of benefit to users of the JCMT, such as instrument availability and proposal info, newsletter releases, etc. If you would like to subscribe, please send a one-line message saying

subscribe jcmt\_users your.email@address.stuff

to "majordomo@jach.hawaii.edu". Many thanks!

Regards, Gerald Moriarty-Schieven

## *New Jobs*

### **Postdoctoral Fellowship in Computational Astrophysics of Star Formation**

#### **Univ. of California, Berkeley, Dept. of Astronomy**

Applications are invited for a postdoctoral fellowship in computational astrophysics of star formation at the UC Berkeley Department of Astronomy beginning on or before 1 September 2003 for an initial period of two years. The position will be offered in conjunction with the NASA Astrophysical Theory Program. Depending upon the availability of funding, a third year may be possible. The successful candidate will hold a PhD in astronomy, astrophysics or physics and have experience in computational astrophysical fluid dynamics, preferably including MHD. Salary will be commensurate with experience.

The postdoctoral fellow will conduct code development and research in low-mass and high-mass star formation using state-of-the-art adaptive mesh refinement (AMR) MHD codes with Profs. Richard I. Klein and Christopher F. McKee. Access to substantial computing resources at national supercomputer centers supporting this research will be made available. The University of California Berkeley is committed to Employment Equity and encourages applications from all qualified candidates.

Applicants should send a curriculum vitae, bibliography, and a statement of their research interests, and arrange for three letters of recommendation to be sent by 31 March 2003 to Prof. Richard I. Klein at the address below.

UNIVERSITY OF CALIFORNIA, BERKELEY, DEPARTMENT OF ASTRONOMY

601 Campbell Hall

Berkeley, California 94720, USA

Tel: 925-422-3548

Email Inquiries: rklein@astron.berkeley.edu

Attention: Richard I. Klein, Professor of Astronomy

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), *Abstracts of recently accepted major reviews* (only for large scale reviews, see Editorial in SFNL#125 for details), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

**Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter.**

The Star Formation Newsletter is available on the World Wide Web at <http://www.ifa.hawaii.edu/~reipurth> or at <http://www.eso.org/gen-fac/pubs/starform/>.

## *Meetings*

# **Protostars and Planets V**

**24 - 28 October 2005**

**Hilton Waikoloa Village, The Big Island, Hawaii**

The Protostars and Planets meetings date back to 1978, when Tom Gehrels had the vision to "develop the interface between studies of star formation and those of the origin of the solar system". Throughout a series of highly successful meetings, the overall goal has remained to bring scientists from the star formation community, planetologists, and meteoriticists together approximately every 7 years to review what we have learned in this exciting interface between disciplines.

The time has now come to begin preparations for Protostars and Planets V. The discovery of extrasolar planets, and rapid advances in our understanding of circumstellar disks, planet formation, the Kuiper belt, and chondrule and CAI formation, to mention only a few areas, promise that PP-V will be an exciting meeting. The goals of the meeting are four-fold: 1) to present an overview of the major areas of progress since PP-IV; 2) to bring researchers together for discussions and exchanges of ideas; 3) to strengthen future interdisciplinary research in these areas; and 4) to encourage the participation of young researchers and advanced students in these fields of research.

The motivation for holding PP-V in Hawaii is based on recent efforts to develop interdisciplinary research in these areas within the University of Hawaii. The Institute for Astronomy, in close collaboration with the Hawaii Institute of Geophysics and Planetology, recently started a Center for Star and Planet Formation in order to specifically explore the interfaces between studies of the early solar system through Kuiper belt objects, comets, and meteorites, and studies of the formation of stars and planetary systems.

### **Organisers:**

Bo Reipurth (Chair) (Institute for Astronomy, Univ. of Hawaii, Honolulu, USA)

David Jewitt (Institute for Astronomy, Univ. of Hawaii, Honolulu, USA)

Klaus Keil (Hawaii Institute for Geophysics, Univ. of Hawaii, Honolulu, USA)

### **Scientific Advisory Committee:**

John Bally (CASA, Univ. of Colorado, Boulder, USA)

Alan Boss (Department of Terrestrial Magnetism, Carnegie Institution of Washington, USA)

Jerome Bouvier (Laboratoire d'Astrophysique, Observatoire de Grenoble, France)

Nuria Calvet (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA)

Cathie Clarke (Institute of Astronomy, Cambridge, UK)

Scott Kenyon (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA)

Katharina Lodders (Department of Earth and Planetary Sciences, Washington University, Saint Louis, USA)

Guenther Lugmair (Max Planck Institut fuer Chemie, Mainz, Germany)

Renu Malhotra (Department of Planetary Sciences, Univ. of Arizona, Tucson, USA)

Michel Mayor (Geneva Observatory, Sauverny, Switzerland)

Michael Meyer (Steward Observatory, Department of Astronomy, Univ. of Arizona, Tucson, USA)

Allesandro Morbidelli (Observatoire de la Cote d'Azur, Nice France)

Antonella Natta (Osservatorio Astrofisico di Arcetri, Firenze, Italy)

Luis Felipe Rodriguez (Instituto de Astronomia, Morelia, Mexico)

Ewine van Dishoeck (Leiden Observatory, Leiden, The Netherlands)

Hans Zinnecker (Astrophysikalisches Institut, Potsdam, Germany)

As further information becomes available, it will be posted at the web site of the conference:

**<http://www2.ifa.hawaii.edu/cspf/ppv/ppv.html>**