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Abstracts of recently accepted papers

Observational Implications of Precessing Protostellar Discs and Jets

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We consider the dynamics of a protostellar disc in a binary system where the disc is misaligned with the orbital plane of the binary, with the aim of determining the observational consequences for such systems. The disc wobbles with a period approximately equal to half the binary's orbital period and precesses on a longer timescale. We determine the characteristic timescale for realignment of the disc with the orbital plane due to dissipation. If the dissipation is determined by a simple isotropic viscosity then we find, in line with previous studies, that the alignment timescale is of order the viscous evolution timescale. However, for typical protostellar disc parameters, if the disc tilt exceeds the opening angle of the disc, then tidally induced shearing within the disc is transonic. In general, hydrodynamic instabilities associated with the internally driven shear result in extra dissipation which is expected to drastically reduce the alignment timescale. For large disc tilts the alignment timescale is then comparable to the precession timescale, while for smaller tilt angles δ , the alignment timescale varies as $(\sin \delta)^{-1}$. We discuss the consequences of the wobbling, precession and rapid realignment for observations of protostellar jets and the implications for binary star formation mechanisms.

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Preprints are available at: <http://www.ast.cam.ac.uk/~mbate/>

The ISO spectroscopic view of the HH 24-26 region

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We report the results of an investigation, performed with the ISO spectrometers (LWS and SWS), on the star forming region associated with the Herbig-Haro objects HH 24-25 and 26. Low-resolution LWS spectra (45-197 μm) were observed towards the HH24MMS, HH25MMS and HH26IR sources as well as the HH26IR outflow. In addition, SWS scans of the pure H_2 rotational lines towards HH24MMS were acquired. Emission from [OI] 63 μm and [CII] 158 μm appears widespread while molecular transitions of carbon monoxide and water vapour were detected only towards

HH25MMS and the blue lobe of HH26IR. From the analysis of the observed emission we deduce that the gas towards HH24MMS and HH25MMS is excited at densities $\sim 10^6 \text{ cm}^{-3}$ and temperatures ranging from 650 to 1400 K in HH24MMS and from 150 to 550 K in HH25MMS. Along the blue lobe of the HH26IR outflow, a more diffuse ($n_{\text{H}_2} \sim 10^4 \text{ cm}^{-3}$) and warm ($T \sim 1800 \text{ K}$) gas is found. Both the molecular (CO, H₂O and H₂) and atomic ([OI]) emission in the three sources can be interpreted as due to shock excitation, and a mixture of both *C*- and *J*-type shocks are required to reproduce most of the observed characteristics of the spectra. The derived water abundances ($3 \cdot 10^{-7}$ - $9 \cdot 10^{-6}$) are lower than expected in warm shock excited gas, a result which has also been found in other similar regions investigated with ISO. The total cooling derived from the gas component traced by the FIR lines is always of the same order or larger than the cooling due to the molecular hydrogen as traced by the H₂ 2.12 μm line; although this latter could be underestimated if the dust extinction is not negligible, however it is evident that a significant fraction of the energy released in the shocks is re-radiated away by the far infrared lines. Finally, the [CII]158 μm line intensities are rather constant at all of the observed positions, excluding the presence of strong photo-dissociation regions related to the nearby IR sources.

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Possible Rapid Gas Giant Planet Formation in the Solar Nebula and Other Protoplanetary Disks

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Gas giant planets have been detected in orbit around an increasing number of nearby stars. Two theories have been advanced for the formation of such planets, core accretion and disk instability. Core accretion, the generally accepted mechanism, requires several million years or more to form a gas giant planet in a protoplanetary disk like the solar nebula. Disk instability, on the other hand, can form a gas giant protoplanet in a few hundred years. However, disk instability has previously been thought to be important only in relatively massive disks. New three dimensional, “locally isothermal”, hydrodynamical models without velocity damping show that a disk instability can form Jupiter-mass clumps, even in a disk with a mass ($0.091M_{\odot}$ within 20 AU) low enough to be in the range inferred for the solar nebula. The clumps form with initially eccentric orbits, and their survival will depend on their ability to contract to higher densities before they can be tidally disrupted at successive periastrons. Because the disk mass in these models is comparable to that apparently required for the core accretion mechanism to operate, the models imply that disk instability could obviate the core accretion mechanism, in the solar nebula and elsewhere.

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Timescales of Disk Evolution and Planet Formation

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We present high-spatial resolution HST and ground-based adaptive optics observations, and high-sensitivity ISO (ISOCAM & ISOPHOT) observations of a sample of X-ray selected weak-line (WTTS) and post (PTTS) T Tauri stars located in the nearby Chamaeleon T and Scorpius-Centaurus OB associations. HST/NICMOS and adaptive optics

observations aimed at identifying substellar companions (young brown dwarfs) at separations ≥ 30 A.U. from the primary stars. No such objects were found within 300 A.U. of any of the target stars, and a number of faint objects at larger separations can very likely be attributed to a population of field (background) stars. ISOCAM observations of 5 to 15 Myr old WTTS and PTTS in ScoCen reveal infrared excesses which are clearly above photospheric levels, and which have a spectral index intermediate between that of younger (1 to 5 Myr) T Tauri stars in Chamaeleon and that of pure stellar photospheres. The difference in the spectral index of the older PTTS in ScoCen compared to the younger classical and weak-line TTS in Cha can be attributed to a deficiency of smaller size (0.1 to 1 μm) dust grains relative to larger size ($\approx 5 \mu\text{m}$) dust grains in the disks of the PTTS. The lack of small dust grains is either due to the environment (effect of nearby O stars and supernova explosions) or due to disk evolution. If the latter is the case, it would hint that circumstellar disks start to get dust depleted at an age between 5 to 15 Myr. Dust depletion is very likely related to the build-up of larger particles (ultimately rocks and planetesimals) and thus an indicator for the onset of the period of planet formation.

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Embedded Stellar Clusters in the W3/W4/W5 Molecular Cloud Complex

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We analyze the embedded stellar content in the vicinity of the W3/W4/W5 H II regions using the FCRAO Outer Galaxy ¹²CO(1–0) Survey, the IRAS Point Source Catalog, published radio continuum surveys, and new near-infrared and molecular line observations. Thirty-four IRAS Point Sources are identified that have far-infrared colors characteristic of embedded star forming regions, and we have obtained K' mosaics and ¹³CO(J=1–0) maps for 32 of them. Ten of the IRAS sources are associated with an OB star and 19 with a stellar cluster, although three OB stars are not identified with a cluster. Half of the embedded stellar population identified in the K' images is found in just the 5 richest clusters, and 61% is contained in IRAS sources associated with an embedded OB star. Thus rich clusters around OB stars contribute substantially to the stellar population currently forming in the W3/W4/W5 region. Approximately 39% of the cluster population is embedded in small clouds with an average mass of $\sim 130 M_{\odot}$ that are located as far as 100 pc from the W3/W4/W5 cloud complex. We speculate that these small clouds are fragments of a cloud complex dispersed by previous episodes of massive star formation. Finally, we find that 4 of the 5 known embedded massive star forming sites in the W3 molecular cloud are found along the interface with the W4 H II region despite the fact that most of the molecular mass is contained in the interior regions of the cloud. These observations are consistent with the classical notion that the W4 H II region has triggered massive star formation along the eastern edge of the W3 molecular cloud.

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Probing the brown dwarf population of the Chamaeleon I star forming region

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We present observations of a sample of 13 very low mass stars and brown dwarfs in the central region of the Chamaeleon I star forming cloud. The observations include slitless spectroscopy around H α to identify new members, low resolution long-slit visible and near-infrared spectroscopy, deep ROSAT PSPC X-ray observations, and ISOCAM mid-infrared observations. Our sample adds seven new objects to those discussed by Comerón, Rieke, and Neuhäuser (1999, A&A, 343, 477) and extends the range of spectral types up to M8. We study different narrow-band indices as a tool for

detecting and classifying very late-type young stellar objects. As to K -band spectra, we find that the visible features are not appropriate to yield a spectral classification more accurate than a few subclasses at best beyond M6.

None of our sources displays K -band excess emission, but four have excess at $6.7 \mu\text{m}$ suggesting that, although circumstellar disks are common around young very low mass stars, their inner regions are in general not hot enough to radiate significantly in the K band. Mid-infrared emission loosely correlates with $\text{H}\alpha$ emission: sources without mid-IR excesses are always weak $\text{H}\alpha$ emitters, while mid-IR excess sources have a broad range of $\text{H}\alpha$ equivalent widths. X-ray emission is detected for 7 objects with spectral type M6 or later, including one bona-fide brown dwarf and three objects near the border separating stars and brown dwarfs. X-ray to bolometric luminosity ratios are typical of low mass, fully convective stars. The non-detection of X-ray emission at comparable levels from more evolved brown dwarfs suggests that X-ray activity may be restricted to early stages of brown dwarf evolution.

We discuss in detail the temperatures and luminosities of our objects based on their magnitudes and spectra, and use the derived values to estimate masses and ages according to two different sets of pre-main sequence evolutionary tracks. Both sets of models are in good agreement concerning the mass derived for our objects, showing that four of them are bona-fide brown dwarfs, six are transition objects, and three are low mass stars. Derived ages differ significantly depending on the adopted models, especially at the lowest masses. This is mainly due to the objects lying on opposite sides of the deuterium-burning main sequence depending on whether one or another set is used. Using Baraffe et al. (1998, A&A, 337, 403) models for the dating of each object in the area of our survey with mass below $1 M_{\odot}$, we find that most have ages near $2 \cdot 10^6$ years, with a small spread around that value. However, a few objects appear to have ages near $2 \cdot 10^7$ years, suggesting that most, but not all, star formation in that region of Chamaeleon I may have happened almost simultaneously in a recent burst.

Comparing predictions on members of the star forming region based on K -band star counts with the number of members actually identified through $\text{H}\alpha$ emission suggests that sensitive $\text{H}\alpha$ surveys are very efficient in producing a complete or nearly complete magnitude-limited census of young stellar objects in Chamaeleon I. Under the assumption that our sample is complete, we derive a mass function of Chamaeleon I between 0.03 and $1 M_{\odot}$ which can be approximated by a nearly flat powerlaw in logarithmic mass units, in agreement with results for other young aggregates.

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<http://www.eso.org/~fcomeron/publicat.html>

Embedded, Self-Gravitating Equilibria in Sheetlike and Filamentary Molecular Clouds

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Numerical solutions of the isothermal Lane-Emden equation are presented, corresponding to self-gravitating gaseous cores embedded within a finite density envelope of overall cylindrical symmetry. These structures may be members of a fragmentation hierarchy proceeding from sheets, to filaments, to elongated, prolate clumps. The embedded solutions are the first of their kind, and as such represent a significant improvement upon the isolated cloud paradigm used almost exclusively by previous authors. The properties of the equilibria are in reasonable agreement with observations of dense molecular cores in star-forming clouds, despite the fact that there is only one free parameter in the models. We show that this parameter may be identified with the critical wavelength for instability in the parent filament. The implications of further fragmentation and the possible influence of magnetic fields are briefly discussed.

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Ultracompact HII Regions in W49N at 500 AU Scales: Shells, Winds and the Water Maser Source

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We have observed the ionized gas in the star forming region W49N with the National Radio Astronomy Observatory Very Large Array (VLA) at 13 mm and 7 mm, and with the Berkeley Illinois Maryland Association (BIMA) Array at 3.3 mm. These observations vary in resolution from 0.045 arcsec to 0.35 arcsec (500 AU to 4000 AU at a distance of 11.4 kpc). In addition, we have used the VLA to observe water maser emission towards the bright W49N:G sources over a wide velocity range from -435 to 435 km s⁻¹. The high resolution continuum observations reveal the morphologies in the ultracompact sources; most of the sources at 0.045 arcsec resolution appear to have shell or ring morphologies. The 3.3 mm emission observed with the BIMA array is dominated by free-free emission in all of the compact sources. There is no evidence for any spectral breaks corresponding to the emergence of a dust component. Of the seven bright sources in W49N for which multifrequency flux densities have been measured, four are observed to have rising spectral indices, with values ranging from $\alpha=0.3$ to 1.1 and three are observed to be flat ($S_\nu \propto \nu^\alpha$). Those sources with rising spectral indices (A, B1, B2, G1 and G2) also have the broadest radio recombination lines, with $\Delta V_{FWHM} > 45$ km s⁻¹ in the H66 α line (De Pree et al. 1997). High resolution 1.3 cm continuum images made at the same time as the water maser observations have been used to align the maser positions with the high resolution 7 mm continuum to within 0.05 arcsec. The maser positions are closely associated with the G1/G2 sources. The outflow traced by the water masers (Gwinn, Moran & Reid, 1992) appears to be centered within 0.2 arcsec of the G2 peak, the brightest continuum source in the region, but it remains unclear whether this source drives the outflow.

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The search for YSOs from ISOGAL data. Application to the $l = +45$ field

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The 7 and 15 μm observations of the Galaxy obtained by the ISOGAL program offer an unique possibility to investigate and separate the different populations of stars in the Galactic Plane, in particular to study the population of low flux density YSOs which could not be detected with IRAS.

Considering the results obtained by ISOCAM in nearby star forming regions and in other test fields in the Galactic Plane, as well as theoretical indications, we establish criteria of general validity that can be used to select YSOs from the much larger population of Post Main Sequence (Post-MS) stars present in the ISOGAL fields. The selection is based primarily on the position of the sources in the [15] - [7]-[15] diagram, which involves only ISOGAL data and allows to select objects with IR excess as possible YSOs using the survey data alone.

The criteria are applied to five ISOGAL fields centered at $l \sim +45^\circ$ and $b \sim 0^\circ$, covering a total area of 0.504 deg². The total number of point sources detected in both filters above the confidence limits of $[7] < 9.5$ and $[15] < 8$ are 386. The ISOGAL results are compared with radio observations in order to identify high luminosity YSOs out of the larger population of lower luminosity ones. We find 3 high luminosity YSOs plus 3 diffuse sources which are associated with HII regions and 35 lower luminosity YSOs. For low flux densities we find a consistent number of sources (73) detected only at 15 μm which, according to the colour upper limit, are classified as candidate YSOs.

The validity of the adopted criteria for selecting possible YSOs in the ISOGAL fields are also supported by two independent results: 1) the sources classified as YSOs and the candidate YSOs are often associated with diffuse nebulosities visible at 15 μm , landmarks of recent star forming activity, and 2) the numbers of high luminosity and low luminosity YSOs that we have found compare well with the expectations.

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Ambipolar Filamentation of Turbulent Magnetic Fields : A numerical simulation.

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We present the results of a 2-D, two fluid (ions and neutrals) simulation of the ambipolar filamentation process, in which a magnetized, weakly ionized plasma is stirred by turbulence in the ambipolar frequency range. The higher turbulent velocity of the neutrals in the most ionized regions gives rise to a non-linear force driving them out of these regions, so that the initial ionization inhomogeneities are strongly amplified. This effect, the ambipolar filamentation, causes the ions and the magnetic flux to condense and separate from the neutrals, resulting in a filamentary structure.

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X-rays and regions of star formation: a combined ROSAT-HRI/near-to-mid IR study of the ρ Oph dark cloud

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We have obtained two deep exposures of the ρ Oph cloud core region with the *ROSAT High Resolution Imager*. The improved position accuracy ($1''$ – $6''$) with respect to previous recent X-ray observations (*ROSAT PSPC*, and *ASCA*) allows us to remove positional ambiguities for the detected sources. We also cross-correlate the X-ray positions with IR sources found in the *ISOCAM* survey of the same region at 6.7 and $14.3 \mu\text{m}$, in addition to sources (optical and IR) known from ground-based observations, which are young stars (T Tauri stars, with and without circumstellar disks, and protostars). We thus obtain the best-studied sample of X-ray emitting stars in a star-forming region (63 X-ray sources detected, and 55 identified).

We find that there is no statistically significant difference between the X-ray luminosity functions of *HRI*-detected Class II and Class III sources, i.e., T Tauri stars with and without disks, confirming that the contribution of these disks to X-ray emission (for instance by magnetic reconnection between the star and the disk), or to X-ray absorption, must be small.

X-ray variability of T Tauri stars can be studied by comparing the *HRI* data with the previously obtained *PSPC* data, but also using the fact that some *HRI* observations were done at different epochs. The resulting statistics show that most of the sources are variable, and that their variability is consistent with a solar-like (hence magnetic) flare origin.

We use the information given both by the *ISOCAM* survey and by our *HRI* deep exposure to study the T Tauri star population of the ρ Oph dense cores. We confirm that essentially all Class II and Class III sources (embedded T Tauri stars) are X-ray emitters, and that a strong correlation exists between their X-ray luminosity, L_X , and their stellar luminosity, L_* , with $L_X/L_* \sim 10^{-4}$. Most of the new *ISOCAM* Class II sources are not detected, however, which we explain by the fact that their X-ray luminosities “predicted” on the basis of this correlation are too faint to be detected by the *HRI*.

We predict that ~ 40 unknown faint or embedded Class III sources remain to be discovered in X-rays in the *HRI/ISOCAM* overlapping area, down to a limit of $L_X \sim 3 \times 10^{28} \text{ erg s}^{-1}$. We show that the bulk of these unknown Class III sources should be made of low- to very low-mass stars ($M_* < 0.1$ – $0.6 M_\odot$). Prospects for future detections with *XMM-Newton* and *Chandra* are discussed.

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Submillimeter maps of small young clusters in three large globules

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We present submillimeter maps of regions within three large globules, CB 3, CB 34, and L 810. Our maps are centered on three IRAS sources, each of which is associated with a small cluster of near-infrared young stellar objects (YSOs) as seen from deep optical and/or near-infrared observations. We have detected submillimeter sources associated with the YSO clusters. The submillimeter emission appears to be primarily from small clusters of protostars rather than from the sources previously detected in the near-infrared. This result suggests that these large globules are currently adding protostars to these clusters. Thus, star formation within each of these large globules appears to be a continuous process rather than a single, isolated event.

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X-ray emission from Lindroos binary systems

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We present a study of the X-ray emission from binary systems extracted from the Lindroos catalogue (Lindroos 1986) based on the ROSAT All-Sky survey as well as ROSAT PSPC and HRI pointings. The studied sample consists of visual binary systems comprised of early-type primaries and late-type secondaries. The ages of the systems were determined by Lindroos (1985) from $uvby\beta$ photometry of the primaries. These ages range between 33 and 135 Myr, so if the late-type secondaries are physically bound to the early-type primaries, they could be Post-T Tauri stars (PTTS).

We have found strong X-ray emission from several secondaries. This fact together with their optical and IR data, make them *bona fide* PTTS candidates. We have also detected X-ray emission from several early-type primaries and, in particular, from most of the late-B type stars. Because their HRI hardness ratios are similar to those from resolved late-type stars, the presence of an unresolved late-type companion seems to be the cause of this emission.

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Tracing the root of the bipolar jet in IRAS 20126+4104: VLBA observations of H₂O masers

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We present VLBA observations of the H₂O masers towards IRAS 20126+4104, a high-mass young stellar object which is believed to be associated with a rotating disk and a bipolar outflow/jet system collimated along the disk axis. A model fit to the positions and velocities of the maser spots demonstrates that these could arise on a conical surface at the interface between the jet and the surrounding molecular gas. The masers expand from a common centre which coincides, within the uncertainties, with the position of the embedded young stellar object: the expansion velocity is less than that measured on a much larger scale in the SiO(2–1) line and this indicates that the jet is sensitively braked close to its origin by the interaction with the surrounding medium.

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Planet formation is unlikely in equal mass binary systems with $a \sim 50$ AU

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We show that planet formation via both gravitational collapse and core accretion is unlikely to occur in equal mass binary systems with moderate (~ 50 AU) semi-major axes. Internal thermal energy generation in the disks is sufficient to heat the gas everywhere so that spiral structures quickly decay rather than grow or fragment. This same heating will inhibit dust coagulation because the temperatures rise above the vaporization temperatures of many volatile materials. We consider other processes not included in the model and conclude that our temperatures are conservatively estimated (low), i.e. planet formation is less likely in real systems than in the model.

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Numerical Simulations of Steady and Pulsed Non-Adiabatic Magnetised Jets from Young Stars

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In contrast to jets from radio galaxies, energy losses due to radiation effects, atomic hydrogen ionisation/recombination and molecular hydrogen dissociation are important in jets from young stars. Moreover there is now general agreement that magnetic fields may play a very important role not only in the formation of these jets but also their subsequent collimation.

With these ideas in mind we have developed a new multi-dimensional magneto-hydrodynamic second order upwind code that includes the above loss terms. Fluxes at cell interfaces are calculated using a linear approximation and, if this fails, a non-linear iterative solver. The condition $\nabla \cdot \mathbf{B} = 0$ is maintained by including small source terms in the conservation equations.

We found that the propagation dynamics and morphology of magnetised supersonic radiative jets are significantly different to their hydrodynamic counterparts even when $\beta = 8\pi P_{gas}/B^2 \approx 1$. Both steady and pulsed jets were simulated. In particular magnetic fields for the three configurations we tested (helical, toroidal, and poloidal) enhance the jet collimation. For example, longitudinal fields restrict the lateral motion of the flow and a purely toroidal field, through hoop stresses, constricts the jet towards its axis. Such stresses, in the toroidal field case, may lead to the jet exhibiting extended nose cones, enhanced bow shock speeds, and disruption of internal working surfaces (knots) formed by velocity variations in the jet. We found that a poloidal field maintained a more stable degree of collimation and the knots were not destroyed. Cooling also improved the jet collimation as it reduced the thermal support in the cocoon making it narrower than its adiabatic counterpart. Another effect of cooling was that it gave rise to Rayleigh-Taylor (RT) unstable configurations at the head of the jet causing the bow shock to periodically break up into smaller structures that sank back into the jet cocoon. This could explain some of the knotty structures seen in Herbig-Haro bows.

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The morphology of clumps in molecular clouds excited by radiation from HH objects

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We have investigated the influence of the radiation field from a Herbig-Haro object on a spherical clump, as the HH object passes by the clump. We have included a limited chemistry, and show column density maps of HCO^+ and NH_3 to represent the morphology of the predicted emission regions. The morphology is sensitive both to the orientation of the line of sight with respect to the HH trajectory and the clump, and to the extinction of the clump. Emission regions may appear bar-like, arc-like, or clump-like. The fractional abundances within these structures are observationally significant. However, the clump is not significantly heated by the radiation, and no clump evaporation occurs during the passage of the HH object for cases where the trajectory does not impact on the clump.

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Hubble Space Telescope NICMOS Images of Herbig-Haro Energy Sources: [FeII] Jets, Binarities, and Envelope Cavities

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We have observed seven regions surrounding the driving sources of Herbig-Haro flows using the NICMOS infrared camera onboard the *Hubble Space Telescope*. These Herbig-Haro energy sources, which power the HH 34, 47, 83, 111, 199, 300, and 454 flows, have all been previously detected in the centimeter wavelength radio continuum. The regions were imaged in two broadband filters, F160W and F205W, which, in addition to stellar continuum, principally transmit the [FeII] 1.644 μm and H_2 2.122 μm lines, respectively, of shocks present in the images. Highly collimated infrared jets emerge from the sources of HH 34, 111, 300, and 454. In all of these cases, the [FeII] emission transmitted in the F160W filter is much stronger than the H_2 emission in the F205W band. Combined with previously published NICMOS images of the bright [FeII] HH 1 jet, these data suggest that [FeII] emission may be as important a tracer of shocked jets in the infrared as [SII] emission is in the optical. [FeII] emission may be enhanced near the driving sources relative to the H_2 emission by a combination of high jet density and strong far-ultraviolet (7.6 – 13.6 eV) radiation from the forming star. The HH 454 [FeII] jet, which emanates from the L1551-NE source, is pointed directly at the bright shock HH 29, providing further evidence that this young star, rather than L1551 IRS5, is the source of the brightest Herbig-Haro object in the L1551 outflow complex. In five regions, the driving sources are visible at 2 μm . Among these, the sources powering HH 47 and HH 300 are found to be binary stars. One other young stellar system, the source of the HH 111 proto-stellar jet, is triple. When combined with other studies, these results indicate that 36% of 14 Herbig-Haro energy sources observed with NICMOS are multiple at near-infrared wavelengths with component separations greater than 0.15 to 0.20 arcsec. Therefore, considering incompleteness, obscuration, and faintness of possible companions in the observed bands, the binary frequency is likely to be considerably higher among the selected systems than among low mass main sequence dwarf stars. There is no obvious connection between source multiplicity and jet morphology observed on large scales. For example, the beam of the HH 47 jet exhibits quasi-periodic wiggles which might be one indication of jet modulation at the binary orbital period. However, the total mass of the observed central binary would have to be unrealistically large to make the orbital period comparable to the ejection time interval of these jet features. Finally, the properties of the near-infrared reflection nebulae associated with the observed sources are investigated. The shapes of the cavity walls traced by the observed reflection nebulae indicate the presence of large scale and highly flattened circumstellar structures which are opaque at near infrared wavelengths. Their flaring shapes are either the result of preferential infall of the protostellar envelope along the outflow axis, or were carved by wide-angle winds emerging from the inner disk and the forming star. The inclination angles of several circumstellar structures are estimated.

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Near-infrared imaging polarimetry of the GG Tau circumbinary ring

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We present 1 micron Hubble Space Telescope/NICMOS resolved imaging polarimetry of the GG Tau circumbinary ring. We find that the ring displays east-west asymmetries in surface brightness as well as several pronounced irregularities, but is smoother than suggested by ground-based adaptive optics observations. The data are consistent with a 37 deg system inclination and a projected rotational axis at a position angle of 7 deg east of north, determined from millimeter imaging. The ring is strongly polarized, up to 50 sub-micron dust grains. Although the polarization pattern is broadly centrosymmetric and clearly results from illumination of the ring by the central stars, departures from true centrosymmetry and the irregular flux suggest that binary illumination, scattering through unresolved circumstellar disks, and shading by these disks, may all be factors influencing the observed morphology. We confirm a 0.25 arcsec shift between the inner edges of the NIR and millimeter images and find that the global morphology of the ring and the polarimetry provide strong evidence for a geometrically thick ring. A simple Monte Carlo scattering simulation is presented which reproduces these features and supports the thick ring hypothesis. We cannot confirm filamentary streaming from the binary to the ring, also observed in the ground-based images, although it is possible that there is material inside the dynamically cleared region which might contribute to filamentary deconvolution artifacts. Finally, we find a faint 5th point source in the GG Tau field which, if it is associated with the system, is almost certainly a brown dwarf.

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A New Association Of Post-T Tauri Stars Near The Sun

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Observing ROSAT sources in an area $20^\circ \times 25^\circ$ centered at the high latitude $b = -59^\circ$ active star ER Eri, we found evidences for a nearby association, that we call the Horologium Association (HorA), formed by at least 10 very young stars, some of them being bona fide Post-T Tauri stars. We suggest other six stars as possible members of this proposed association. We examine several requirements that characterize a young stellar association. Although no one of them, isolated, gives an undisputed prove of the existence of the HorA, all together practically create a strong evidence for it. In fact, the Li line intensities are between those of the older classical T Tauri stars and the ones of the Local Association stars.

The space velocity components, of the HorA relative to the Sun ($U = -9.5 \pm 1.0$, $V = -20.9 \pm 1.1$, $W = -2.1 \pm 1.9$) are not far from those of the Local Association, so that it could be one of its last episodes of star formation. In this region of the sky there are some hotter and non-X-ray active stars, with similar space velocities, that could be the massive members of the HorA, among them, the nearby Be star Achernar. The maximum of the mass distribution function of its probable members is around $0.7 - 0.9 M_\odot$. We estimate its distance as ~ 60 pc and its size as ~ 50 pc. If spherical, this size would be larger than the surveyed area and many other members could have been missed. We also observed 3 control regions, two at northern and southern galactic latitudes and a third one in the known TW Hya Association (TWA), and the properties and distribution of their young stars strengthen the reality of the HorA. Contrary to the TWA, the only known binaries in the HorA are 2 very wide systems. The HorA is much more isolated from clouds and older (~ 30 Myr) than the TWA and could give some clues about the lifetime of the disks around T Tauri stars. Actually, none of the proposed members is an IRAS source indicating an advanced stage of the evolution of their primitive accreting disks. ER Eri itself was found to be a RSCVn-like system.

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An IUE Atlas of Pre–Main–Sequence Stars: I. Coadded Final Archive Spectra from the SWP Camera J. A. Valenti^{1,2}, C. M. Johns–Krull^{2,3}, J. L. Linsky³

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We have identified 50 T Tauri stars (TTS) and 74 Herbig Ae/Be (HAEBE) stars observed in the IUE short wavelength bandpass (1150–1980 Å). Each low resolution ($R \sim 6$ Å) spectrum was visually inspected for source contamination and data quality, and then all good spectra were combined to form a single time averaged spectrum for each star. Use of IUE Final Archive spectra processed with NEWSIPS reduces fixed pattern noise in individual spectra, allowing significant S/N gains in our coadded spectra. For the TTS observed by IUE, we measured fluxes and uncertainties for 17 spectral features, including two continuum windows and four fluoresced H₂ complexes. Thirteen of the 32 accreting TTS observed by IUE have detectable H₂ emission, which until now had only been reported for T Tau. Using an empirical correlation between H₂ and C IV line flux, we show that lack of sensitivity can account for practically all nondetections, suggesting that H₂ fluorescence may be intrinsically strong in all accreting TTS systems. Comparison of IUE and GHRS spectra of T Tau show extended emission primarily but not exclusively in lines of H₂. We also fit reddened main sequence templates to 72 HAEBE stars, determining extinction and checking spectral types. Several of the HAEBE stars could not be fit well or yielded implausibly low extinctions, suggesting the presence of a minority emission component hotter than the stellar photosphere, perhaps due to white dwarf companions or heating in accretion shocks. We identified broad wavelength intervals in the far UV that contain circumstellar absorption features ubiquitous in B5–A4 HAEBE stars, declining in prominence for earlier spectral types, perhaps due to increasing ionization of metal resonance lines. For 61 HAEBE stars, we measured or set upper limits on a depth index that characterizes the strength of circumstellar absorption, comparing this depth index with published IR properties.

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ISO Spectroscopy of the Young Bipolar Nebulae S106 IR and Cep A East

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We present the results of ISO SWS and LWS grating scans towards the embedded Young Stellar Objects (YSOs) S106 IR and Cep A East. Emission from the pure rotational lines of H₂ and the infrared fine structure lines of [C II], [O I], [S I], [Si II] and [Fe II], as well as absorption bands due to H₂O, CO and CO₂ ice were detected toward Cep A. In S106 we detected emission lines of H₂, CO, H I, and a large number of ionized species including Fe, O, N, C, Si, S, Ne and Ar. S106 also shows many of the infrared PAH bands in emission. Excitation temperatures and molecular hydrogen masses were derived from the low-lying pure rotational levels of H₂ and are 500 and 730 K and 8 and $3 \times 10^{-3} M_{\odot}$ for S106 and Cep A, respectively. Since both objects are expected to have several solar masses of H₂ in their environment, we conclude that in both cases the bulk of the H₂ is cooler than a few hundred Kelvins. Excitation temperatures and line ratios were compared with those predicted by theoretical models for PDRs and dissociative and non-dissociative shocks. The [S I] 25.2 μm/[Si II] 34.8 μm ratio is a particularly useful shock versus PDR discriminant and we conclude that S106 IR is dominated by PDR emission while Cep A East has a large shock component. From an analysis of the ionic lines in S106 we conclude that the central star must have a temperature around 37,000 K, corresponding to a spectral type of O8. From its luminosity it is concluded that the driving source of Cep A must also be a massive early-type star. The absence of strong high-ionization ionic lines in its ISO spectrum shows that Cep A has not yet created a significant H II region and must be younger than S106, illustrating the process of the clearing of the surroundings of a massive young star.

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<http://cfa-www.harvard.edu/sfgroup/>

Giant Molecular Outflows Powered by Protostars in L1448

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We present sensitive ($T_R^* \approx 0.1\text{K}$), large-scale ($47' \times 7'$ —corresponding to $4 \text{ pc} \times 0.6 \text{ pc}$ at the source) maps of the CO J=1→0 emission of the L1448 dark cloud at $55''$ resolution. These maps were acquired using the On-The-Fly (OTF) capability of the NRAO 12-meter telescope atop Kitt Peak in Arizona. CO outflow activity is seen in L1448 on parsec-scales for the first time. Careful comparison of the spatial and velocity distribution of our high-velocity CO maps with previously published optical and near-infrared images and spectra has led to the identification of six distinct CO outflows. Three of these are powered by the Class 0 protostars, L1448C, L1448N(A), and L1448N(B). L1448 IRS 2 is the source of two more outflows, one of which is newly identified from our maps. The sixth newly discovered outflow is powered by an as yet unidentified source outside of our map boundaries.

We show the direct link between the heretofore unknown, giant, highly-collimated, protostellar molecular outflows and their previously discovered, distant optical manifestations. The outflows traced by our CO mapping generally reach the projected cloud boundaries. Integrated intensity maps over narrow velocity intervals indicate there is significant overlap of blue- and redshifted gas, suggesting the outflows are highly inclined with respect to the line-of-sight, although the individual outflow position angles are significantly different. The velocity channel maps also show that the outflows dominate the CO line cores as well as the high-velocity wings. The magnitude of the combined flow momenta, as well as the combined kinetic energy of the flows, are sufficient to disperse the $50 M_\odot$ NH_3 cores in which the protostars are currently forming, although some question remains as to the exact processes involved in redirecting the directionality of the outflow momenta to effect the complete dispersal of the parent cloud.

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Dissertation Abstracts

The Structure of Interstellar Molecular Clouds: Observations and Δ -variance Analysis

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Ph.D degree awarded: Feb 1999

Stars form in the denser regions of molecular clouds. The details of the star formation process, however, are not fully understood. The physical processes responsible for the observed complex and filamentary molecular cloud structure are not known in detail although it is widely accepted that turbulence plays an important role. The quantitative treatment of turbulence is notoriously difficult and for the interstellar medium it is complicated by the high compressibility of the gas and the presence of magnetic fields. A quantitative deduction of the spatial and velocity structure from first principles is currently not possible. Therefore, a different approach is used to identify the relevant physical processes for molecular clouds: the structure in observed molecular cloud images is quantified, which allows a comparison to simulations of structure formation by individual processes, such as magneto-hydrodynamic turbulence. A systematic analysis for different molecular clouds (e.g. quiescent, star-forming clouds) then in principle allows to trace the evolution of molecular clouds from molecular cloud to star formation and to deduce key parameters such as the star formation rate and efficiency, and the initial mass function of the newly formed stars.

This thesis studies the structure of nearby ($d \sim 150$ pc) quiescent molecular clouds which have not (yet) given birth to new stars. Observations are made with the KOSMA 3m telescope in the rotational transitions of CO and its isotopomers toward MCLD 123.5+24.9 (a translucent cloud in the Polaris Flare), L1512 and L134A. They complement observations made at high angular resolution (11'' and 22'') with the 30m telescope (IRAM key-project) and existing large-scale surveys. The resulting data set allows to study the cloud structure on more than three decades in linear scale, from ~ 10 pc down to 1800 AU.

The accurate intensity calibration of the observations is critical to a later structure analysis. Residual errors significantly affect the results obtained, and potentially dominate them in extreme cases. In observed maps, point-to-point variations of the intensity calibrations typically result from receiver gain drifts or the imperfect correction for the atmospheric attenuation. In this thesis, methods for a self-consistent correction of these systematic errors are studied and successfully applied to the observed spectral line maps. The influence of the error beam (stray radiation) pick-up in single dish observations is studied and correction tools are developed and compared with respect to their accuracy and limitations. The correction of the IRAM key-project data shows that up to 50% of the intensity in each map is due to error beam pick-up. In addition, the line profiles are significantly modified. The corrected maps show a significantly enhanced contrast.

The quantitative characterization of the molecular cloud structure is done using the Δ -variance. Introduced by Stutzki et al. (1998), the Δ -variance allows to study the spatial drift behavior of scalar functions, such as the intensity distribution of molecular cloud tracers. For images with a power law power spectrum and random phases, known as *fractional Brownian motion (fBm) structures*, the Δ -variance analysis allows to determine the spectral index β of the power spectrum. A detailed study of the influence of the finite image size (edge effects), white noise and beam smearing is done. Compared to the power spectrum itself, the Δ -variance is more robust with respect to edge-effects and allows a better discrimination of the structure against white noise. The Δ -variance is applied to the observed spectral line maps and the Bell Labs $^{13}\text{CO}(1-0)$ molecular cloud surveys. For the velocity integrated maps, the spatial structure of the emission is well characterized by a power law power spectrum. The spectral index is remarkably uniform for different molecular clouds and linear scales larger than ~ 0.5 pc ($2.5 \leq \beta \leq 2.8$). Significantly larger indices ($\beta \gtrsim 3$) are found for observations made at higher spatial resolution toward MCLD 123.5+24.9, suggesting that the structure is smoother at smaller scales.

<http://chandra.ph1.uni-koeln.de/bensch/astro/publications.html>

Circumstellar Dust: From Protostars to Planetary Systems

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A combination of theoretical work and observational discoveries over the past three decades has led to significant advances in our understanding of the star and planet formation process. However, many important questions remain to be addressed, especially regarding the earliest phases of protostellar collapse and the transformation of circumstellar disks into planetary systems. In this thesis, I have undertaken a theoretical study of “Class 0” protostars and an observational investigation of the evolution of protoplanetary disks, diversity of planetary debris systems, and the kinship between dusty remnants and planets, using a new generation of infrared and sub-millimeter instruments.

I present radiative transfer calculations of infalling envelopes surrounding Class 0 sources, compare them to the observed spectral energy distributions and radial intensity profiles, and derive mass infall rates. The rapid infall, probably inevitable given their dense environments, and the relatively flat inferred density distribution, perhaps due to contributions from external cloud material, lead us to suggest that many Class 0 sources could be the protostars of dense regions.

It has been suggested that circumstellar disks evolve from massive, optically thick, actively accreting structures to low-mass, optically thin, passive remnants in about 10 Myr. That transition may mark the assembly of grains into planetesimals, or clearing of the disk by planets. I present mid-infrared observations of the TW Hydrae Association, a recently-identified nearby group of 10-Myr-old stars. The results suggest rapid evolution of inner disks as does our discovery of a spatially-resolved disk with a central cavity around the young A star HR 4796A. I also present the results of mid-infrared imaging of 11 other Vega-like stars, derive global properties of the dust disks, place constraints on their sizes, and discuss several interesting cases in detail. Finally, I report the detection of dust emission from a possible Kuiper Belt around 55 Cancri, a star with known planetary companion(s).

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Meetings

Emission Lines from Jet Flows

Isla Mujeres, México

November 13-17, 2000

Coordinators: L. Binette and A. C. Raga

This meeting is meant to bring together researchers in the fields of emission line jets from stars and from galaxies. These two fields have many common challenges and problems, and we feel that it would be interesting to have an opportunity for a mutual exchange of ideas. The conference will have approximately 10 review talks, and a number of shorter talks on related subjects. In particular, the topics of HH objects, molecular outflows, jets in photoionized regions, jets from Seyfert galaxies and jets from other active galaxies (at low and at high z) will be covered. Particular emphasis will be given to discussions of the excitation mechanisms (shocks, turbulence and photoionization) of the emission line spectra of the jets.

The conference will take place in Isla Mujeres, which is at an approximately 30 minute taxi+boat ride from Cancún airport.

For further information about the scientific or other aspects of the conference, please contact:

A. Raga or L. Binette (at: jet2000@astroscu.unam.mx).

Further information and electronic registrations are available at the web site:

<http://www.astroscu.unam.mx/jet2000>

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