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Abstracts of recently accepted papers

The Polarizing Power of the Interstellar Medium in Taurus

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We present a study of the polarizing power of the dust in cold dense regions (dark clouds) compared to that of dust in the general interstellar medium (ISM). Our study uses new polarimetric, optical, and spectral classification data for 36 stars to carefully study the relation between polarization percentage (p) and extinction (A_V) in the Taurus dark cloud complex. We find two trends in our $p - A_V$ study: (1) stars background to the warm ISM show an increase in p with A_V; and (2) the percentage of polarization of stars background to cold dark clouds does not increase with extinction. *We detect a break in the $p - A_V$ relation at an extinction 1.3 ± 0.2 mag, which we expect corresponds to a set of conditions where the polarizing power of the dust associated with the Taurus dark clouds drops precipitously. This breakpoint places important restrictions on the use of polarimetry in studying interstellar magnetic fields.*

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Interpreting the Mean Surface Density of Companions in Star-Forming Regions

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We study the interpretation of the mean surface density of stellar companions as a function of separation (or, equivalently, the two point correlation function of stars) in star-forming regions. First, we consider the form of the functions for various simple stellar distributions (binaries, global density profiles, clusters, and fractals) and the effects of survey boundaries.

Following this, we study the dependencies of the separation at which a transition from the binary to the large-scale clustering regime occurs. Larson (1995) found that the mean surface density of companions follows different power-law functions of separation in the two regimes. He identified the transition separation with the typical Jeans length in the molecular cloud. However, we show that this is valid only for special cases. In general, the transition separation depends on the volume density of stars, the depth of the star-forming region, the volume-filling nature of the stellar distribution, and on the parameters of the binaries. Furthermore, the transition separation evolves with time. We also note that in young star-forming regions, binaries with separations greater than the transition separation may exist, while in older unbound clusters which have expanded significantly, the transition contains a record of the stellar density when the stars formed.

We then apply these results to the Taurus-Auriga, Ophiuchus, and Orion Trapezium star-forming regions. We find

that while the transition separation in the Taurus-Auriga star-forming region may indicate a typical Jeans length, this is not true of the Orion Trapezium Cluster. We caution against over-interpreting the mean surface density of stellar companions; while Larson showed that Taurus-Auriga is consistent with the stars having a fractal large-scale distribution we show that Taurus-Auriga is also consistent with stars being grouped in non-hierarchical clusters. We also argue that to make a meaningful study of the stellar distribution in a star-forming region requires a relatively complete stellar survey over a large area. Such a survey does not currently exist for Ophiuchus. Finally, we show that there is no evidence for sub-clustering or fractal structure in the stars of the Orion Trapezium Cluster. This is consistent with the fact that, if such structure were present when the stars formed, it would have been erased by the current age of the cluster due to the stellar velocity dispersion.

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http://www.mpia-hd.mpg.de/theory/bate

On the Formation of Massive Stars

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We present a model for the formation of massive ($M \gtrsim 10 M_\odot$) stars through accretion-induced collisions in the cores of embedded dense stellar clusters. This model circumvents the problem of accreting onto a star whose luminosity is sufficient to reverse the infall of gas. Instead, the central core of the cluster accretes from the surrounding gas, thereby decreasing its radius until collisions between individual components become significant. These components are, in general, intermediate-mass stars that have formed through accretion onto low-mass protostars. Once a sufficiently massive star has formed to expel the remaining gas, the cluster expands in accordance with this loss of mass, halting further collisions. This process implies a critical stellar density for the formation of massive stars, and a high rate of binaries formed by tidal capture.

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Astrometric Signatures of Giant Planet Formation

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The discovery of evidence for giant planets orbiting nearby solar-type stars prompts a reconsideration of their formation mechanisms. Two mechanisms have been advanced for giant planet formation, core accretion and disk instability, with very different implications for the epoch of giant planet formation. If giant planets form through collisional accumulation leading to 10-Earth-mass ice and rock cores, followed by hydrodynamical accretion of envelope gas, then young stellar objects (YSOs) should show little astrometric wobble until ages of about 10 to 20 million years (Myr) are reached. However, if giant planets instead form directly through gravitational instability of protoplanetary disks, then observable astrometric wobbles should be seen within a few hundred years after the onset of the disk instability, i.e., even in the youngest YSOs, with ages as little as 0.1 Myr. We present here the astrometric signature to be expected for a YSO experiencing disk instability and giant gaseous protoplanet formation, as calculated by a three dimensional hydrodynamics code. Astrometric measurements of a suitable ensemble of optically-visible YSOs in nearby star-forming regions should be able to determine which of the two mechanisms is responsible for giant planet formation.

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An Analytic Solution to the Hypersonic, Radiative Blunt Body Problem

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We present an analytic model for the thin shell, radiative interaction between a hypersonic, plane-parallel wind and a rigid, spherical obstacle. This problem has clear applications, e. g., to the interaction of winds from young stars and dense cloudlets, and to the interaction of the wind from a binary partner with the photosphere of the second star. We also present a comparison of the analytic model with a full, axisymmetric numerical simulation. We find only a partial agreement between the numerical simulation and the analytic model, apparently as a result of the very strong "thin shell" instabilities of the post-bow shock flow. Our analytic model predicts the surface density, flow velocity and the energy radiated per unit area, as well as the total luminosity of the bow shock. Therefore, the model can be used directly for carrying out comparisons with observations of different astrophysical objects.

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Pressure Confined Ultracompact HII Regions in Sgr B2 Main

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The ionized gas in the Sagittarius B2 Main star forming region has been imaged with ∼65 mas (500 AU) resolution using the Very Large Array (VLA) at 7 mm in the A configuration. These observations have ∼4-5 times the resolution of the previous highest resolution images of this source. These VLA observations show that the central four ultracompact HII (UCHII) regions in Sgr B2 Main (F1, F2, F3 and F4) break up into ∼20 separate UCHII regions. The individual sources have small resolved sizes ($\sim 10^{-3}$ pc), high derived emission measures (EM$\sim 10^{9}$ pc cm^{-6}) and high rms electron densities ($n_e \sim 10^{6}$ cm^{-3}). We compare the observed radius and derived emission measure of each of these regions with those expected for an UCHII region in pressure equilibrium with its environment using previously published temperatures and densities for the Sgr B2 molecular core ($n_{H_2}=2\times10^{7}$ cm^{-3}; Hüttemeister et al. 1993). We find that the observed emission measures are in fact higher than those predicted in a simple pressure confinement model, suggesting that the molecular densities on scales that confine the UCHII regions may be higher than 2×10^{7} cm^{-3}.

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Progressive dispersal of the dense gas in the environment of early-type and late-type Herbig Ae-Be stars

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We have carried out a systematic study of the environment of 14 Herbig Ae/Be (HAEBE) stars at millimeter wavelengths. Our data show that there is a progressive dispersal of the dense gas associated with these stars in their evolution to the main sequence. The efficiency of this dispersal is very different for "early-type" (B0-B5) and "late-type" (B5-A5) stars. While in early-type stars the mean gas density in a radius of 0.08 pc decreases by almost two orders of magnitude during their evolution to the main sequence, in late-type stars it decreases by less than an order of magnitude. Because of this different efficiency, there is no correlation between the ages of the stars and the Hillenbrands' infrared (IR) groups. Early-type stars evolve from the Hillenbrand's Group I to Group III in their way to the

main sequence, while late-type stars evolve from Group II to Group I.

Since the morphology of the parent molecular cloud seems to be strongly dependent on the age of the stars, we propose a new classification for both, early-type and late-type HAEBE stars. We refer as Type I stars to those immersed in a dense clump. These stars are associated with bipolar outflows and have ages $\sim 10^5$ yrs. We call Type III stars those that have completely dispersed the surrounding dense gas and are located in a cavity of the molecular cloud. Bipolar outflows are not associated with them and their ages are $> 10^6$ yrs. Type II stars represent the intermediate case, they are immersed in the molecular cloud but they are not at the peak of a dense clump. The advantage of this new classification is that allows a simple and easy estimate of the evolutionary stage and age of HAEBE stars.

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http://www.oan.es/preprints

The outflow from the class 0 protostar HH 25MMS: methanol enhancement in a well-collimated flow

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We present millimetre and submillimetre observations of HH 25MMS made with the James Clerk Maxwell Telescope (JCMT). From greybody fits to the continuum data we can confirm that HH 25MMS is a class 0 source, with a bolometric luminosity of ~ 6 $L_\odot$ and $T_{\rm bol} = 34 \pm 2$ K. The ratio of submillimetre-to-bolometric luminosity is $\sim$0.05, more than ten times higher than the defining value specified by André et al. (1993).

The radio continuum source lies at the centre of a highly-collimated, jet-driven, bipolar molecular outflow which lies close to the plane of the sky. We have mapped the southern lobe in the emission of CO J=3–2 and find that the CO peaks upstream of the bright H_2 knot HH 25C, indicative of a prompt entrainment mechanism. A plot of the momentum per unit distance along the outflow axis confirms this. Furthermore, the jet shows evidence of a time-varying direction.

The southern lobe is the site of significant methanol enhancement. Maps are presented of the $J_K = 5_K–4_K$ group of lines which show emission solely within the confines of the southern outflow lobe. HH 25MMS is thus only the second class 0 source to have the distribution of methanol mapped within its outflow. Eight further methanol lines have been observed at the position of one of the H_2 knots (HH 25C) to better constrain an estimate of the methanol column density and excitation temperature. The methanol at this position is slightly warmer than the ambient gas with an excitation temperature of 22–34 K and the abundance of methanol is enhanced by a factor of at least 200 over that in the ambient gas. Statisitical equilibrium calculations confirm this although the results are not particularly well constrained. The gas kinetic temperature is somewhat higher than the excitation temperature at $\sim$60 K, the H_2 number density lies within a factor of five of 10^5 cm^{-3} and the abundance is within a factor of 10 of 2.6×10^{-7} relative to H_2.

The SO $J_N = 8_7–7_6$ and SiO J=7–6 lines are also observed within the outflow, emission from the latter being predominantly redshifted relative to the rest velocity.

Copies may be obtained from http://ast.leeds.ac.uk/~agg/research/pubs.html

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Cepheus A East – Unravelling The Mysteries

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New infrared images of Cep A East are presented which show two regions of shock excited line emission from separate bipolar flows. We identify the dominant sources powering the outflows, and argue the results support a multiple outflow model (Narayanan & Walker 1996) as opposed to a quadrupolar outflow scenario. The images include near infrared broad-band (K [2.158 μm], L$''$ [3.81 μm] and M$'$ [4.67 μm]) and spectral line ([FeII] emission line at 1.644 μm and H_2 1–0 S(1) line at 2.122 μm) observations as well as continuum emission at 1.644 μm and 2.122 μm. Considering our data and other results, we present a unified, self-consistent picture of the disk and shock structure. The northern emission region appears to be the result of the ablation of a dense molecular clump (coincident with HW 6) in the path of a diverting jet from YSO HW 2 and subsequent multiple bow shocks with prompt entrainment arising from the interaction of the jet with the molecular cloud CepA-2. The southern line emission region, near HW 7, resembles the 'artillery shell' bow shocks found in Orion, and is most likely a J-type shock caused by a jet from another YSO, possibly HW 3(d)ii.

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http://astro.pas.rochester.edu/ jagoetz/

A Survey of Optical Jets and HH Objects in the ρ Ophiuchi Cloud Core

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We describe a deep narrow-band [S II] imaging survey of ~ 0.7 deg^2 covering the ρ Ophiuchi cloud core (L 1688). We detect 7 new jet/HH objects in our survey: three are new detections, and four confirm candidates from a recent survey by Wilking et al. (1997). Together with the five previously known objects, this brings the total to 12 known jet/HH objects in the cloud. In addition to this, we propose six new candidate HH objects. The most likely sources to power the new jet/HH objects appear to be optically visible stars; however, a conclusive association between the HH objects and pre-main sequence stars is difficult, as several candidate driving sources lie in close vicinity of the new knots. Practically all of the HH objects are located on the perimeter of the cloud. The lack of optical emission toward the center of the cloud, and the high spatial concentration of the youngest protostars toward the densest regions strongly suggests that jets inside the cloud are obscured from our view at optical wavelengths. A near-infrared H_2 survey is required to penetrate into the cloud and to study the outflow activity in this extremely active star-forming region.

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Hubble Space Telescope WFPC2 Observations of HH 1-2

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We present *HST* WFPC2 images of the bipolar Herbig-Haro complex HH 1-2 in three emission lines (Hα, [S II], and [O III]) and one continuum band (F702W). In addition to showing the complex morphology of these objects, the WFPC2 data allow us to resolve the cooling and recombination regions behind radiative shocks. This provides important diagnostics for the properties of the shocks present, including information about the direction of shock propagation and the post-shock cooling length. The HH 1 jet can be interpreted as a series of bow shocks, consistent with models of the propagation of a pulsed jet. Evidence is seen both of the interaction of the jet with its surroundings and internal shocks between knots. Large knot complexes are spaced with a period of around 15 years, while internal structure within these complexes have characteristic separations corresponding to about 3.5 years. Two knots at the base of the HH 1 jet point away from the main jet and do not line up with the outflow source at VLA 1. These may be associated with an outflow from a third source within the VLA 1/2 region.

The HH 1 complex consists of multiple bow shocks which at least in part trace variations in jet direction with time. The misalignment between the direction of the visible HH 1 jet and the jet currently reaching the HH 1 bow shock is direct evidence of such variations. Arches on the west side of HH 1 are smooth, faint, high excitation, and have well resolved post-shock cooling regions. Shoulders on the east side of HH 1 are bright, low excitation, and fragmented. This asymmetry is due to a significant difference in the density and velocity of pre-shock material on either side of HH 1, and can be understood if the HH 1 jet is currently striking the edge of its own outflow cavity. The HH 1 knot F bow shock shows a gap in the [O III] at its apex where the shock is fast enough to ionize beyond O^{++} and the cooling time is long enough for material to flow out of the region before cooling. A nested double bow shock structure at this location may be the result of an incoming knot in a clumpy jet which is just overtaking its decelerated predecessor. Features located between VLA 1 and the HH 1 bow shock probably arise as a broader wind from VLA 1 encounters structure along the wall of the outflow cavity.

HH 2 has an extremely complex structure, but on a feature by feature basis much of the physical structure of HH 2 can be understood, leading to a consistent overall description of the object. The HH 2 jet is currently encountering dense ambient gas. The working surface of the jet is seen as bright, high ionization emission in the central region of the complex. This emission shows a clumpy appearance due largely to the short cooling lengths behind shocks driven into dense material. The larger bow shock accompanying the jet working surface can be traced as well. Flanking the working surface are several locations where a momentum driven shell is fragmenting due to hydrodynamical and thermal instabilities that arise as it, too, runs into dense ambient material. The dense obstacle being encountered by HH 2 is localized. Fossil bow shocks and "splatter" from the jet can be seen moving around this obstacle on either side of HH 2, giving the object its "indented" appearance. As in HH 1, a broader wind accompanies the HH 2 jet. Interaction of this wind with ambient material is responsible for a number of features in HH 2, including the knot seen farthest from the outflow source.

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ftp://wfpc2.la.asu.edu/papers/hh1-2_hst/

ROSAT and Hipparcos Observations of Isolated Pre–Main-Sequence Stars near HD 98800

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We present new observations of the isolated young stars HD 98800 and CD −33°7795. Pointed *ROSAT* observations show that their X-ray properties, including X-ray luminosity and variability, are consistent with those of pre–main-sequence (PMS) stars. These observations do not reveal any additional PMS candidates in 40′ fields centered on HD 98800 and CD −33°7795. Hipparcos observations of TW Hya (Wichmann et al. 1998) and HD 98800 (Soderblom et al. 1998) show that both stars are roughly 50 pc away and are PMS with ages of $\sim 10^7$ yr. We searched the Hipparcos catalog (complete down to $\sim$ 2–3 $L_\odot$ at this distance) for other PMS stars in the same area. In a 10-pc radius volume of space centered on the previously known PMS stars, we find one additional candidate PMS star (CD −36°7429) with a low space velocity, X-ray emission comparable to that of HD 98800, and Li absorption. There are eight other stars in this area that have dwarf spectral types and lie above the main sequence, but based on their weak X-ray emission, high space velocities, and lack of Li in low-resolution spectra (i.e. EW(Li) < 0.1 Å), these are probably mis-classified subgiants or giants. The current positions and proper motions of TW Hya, HD 98800, and CD $-36^\circ 7429$ are inconsistent with them having formed as a group.

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Preprints available at http://gila.la.asu.edu/˜jensen/preprints.html

Additional Periodic Variables in NGC 2264

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We present results from a second season of monitoring fields in the young cluster NGC 2264 at Van Vleck Observatory. In Paper I (Kearns *et al.* 1997)we reported the discovery of 9 periodic variables - all interpreted as spotted pre-main sequence stars. That has now been increased to 31, one of which is quite unusual. The preliminary result reported in Paper I - that the frequency distribution of rotation periods in NGC 2264 is significantly different from what is seen in the Orion Nebula Cluster (ONC) - is confirmed. In particular, the distribution peaks at a period of about 4 days, precisely where there is a gap in the ONC distribution. There is also a good number of very rapidly rotating stars and a long tail of slow rotators. The distribution can be understood, at least qualitatively, in terms of a disk-locking model of rotational evolution. In this interpretation, the majority of stars in NGC 2264 must have unlocked from their disks by an age of about 1 million years, and spun-up roughly in accordance with conservation of angular momentum. A minority (about 20%) are conserving angular velocity instead (i.e. locked to their disks). The unusual star, 15D, has an apparent period of about 48 days and a light curve indicative of an eclipse by a non-stellar object. Its amplitude exceeds 3 magnitudes! Our fragmentary data suggest a complex structure for the eclipsing body. It could be a feature (proto-planet?) in this star's circumstellar disk and, as such, deserves observational attention.

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Optical Spectroscopy of Embedded Young Stars in the Taurus-Auriga Molecular Cloud

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This paper describes the first optical spectroscopic survey of class I sources (also known as embedded sources and protostars) in the Taurus-Auriga dark cloud. We detect 10 of the 24 known class I sources in the cloud at 5500–9000 Å. All detected class I sources have strong Hα emission; most also have strong [O I] and [S II] emission. These data − together with high quality optical spectra of T Tauri stars in the Taurus-Auriga cloud − demonstrate that forbidden emission lines are stronger and more common in class I sources than in T Tauri stars. Our results also provide a clear discriminant in the frequency of forbidden line emission between weak-emission and classical T Tauri stars. In addition to strong emission lines, three class I sources have prominent TiO absorption bands. The M-type central stars of these sources mingle with optically visible T Tauri stars in the HR diagram and lie somewhat below both the birthline for spherical accretion and the deuterium burning sequence for disc accretion.

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http://cfa-www.harvard.edu/∼kenyon/preprints.html

Hubble Space Telescope WFPC2 Imaging of FS Tauri and Haro 6-5B

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We have observed the field of FS Tauri (Haro 6-5) with WFPC2 on the Hubble Space Telescope. Centered on Haro 6-5B and adjacent to the nebulous binary system of FS Tauri A there is an extended complex of reflection nebulosity that includes a diffuse, hourglass-shaped structure. H6-5B, the source of a bipolar jet, is not directly visible but appears to illuminate a compact, bipolar nebula which we assume to be a protostellar disk similar to HH 30. The bipolar jet appears twisted, explaining the unusually broad width measured in ground-based images. We present the first resolved photometry of the FS Tau A components at visual wavelengths. The fluxes of the fainter, eastern component are well matched by a 3360 K blackbody with an extinction of $A_V = 8$. For the western star, however, any reasonable, reddened blackbody energy distribution underestimates the K-band photometry by over two magnitudes. This may indicate errors in the infrared photometry or errors in our visible measurements due to bright reflection nebulosity very close to the star. The binary was separated by $0''.239 \pm 0''005$ at a position angle of $84^\circ \pm 1.5^\circ$ on 1996 January 25. There is no nebulosity around FS Tau A at the orientation suggested for a disk based on previous, ground-based polarization measurements.

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http://scivax.stsci.edu/ krist/fstau.html

High sensitivity search for molecular gas in the β Pic disk

On the low gas-to-dust mass ratio of the circumstellar disk around β Pictoris

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We report on high sensitivity observations of the β Pic system in four molecular transitions with the 15 m SEST, tracing carbon, silicon and sulphur bearing species (CO, SiO and CS) and, as such, the gaseous component of the circumstellar disk. Models of the disk emission in molecular lines show that the lack of signal in the CO (2–1) line is consistent with an interstellar value of CO/H and a very low column density of hydrogen gas [$N(\mathrm{H}) < 10^{19}\,\mathrm{cm}^{-2}$]. The data do not require that CO is severely depleted with respect to hydrogen. Rather, we find that the gas-to-dust mass ratio in the disk is abnormally low, viz. $m_{\mathrm{gas}}/m_{\mathrm{dust}} < 0.1$ (< 0.05 at the $1\,\sigma$ level), implying an upper limit to the mass of hydrogen gas $m(\mathrm{H}) < 2\,10^{-2}\,\mathrm{M}_\oplus$ ($5\,\mathrm{M}_{\mathrm{Moon}}$). Evidently, any nebular disk gas from the formation stage of β Pic has been consumed in planet formation and/or blown out during the early mass loss history of the system.
The sensitive search for SiO gas, believed to be presently produced in evaporative grain-grain collisions, gave likewise negative results. From the modeling of the line emission from the β Pic disk we deduce that this non-detection could be explained by insufficient filling of the SEST beam and that the testing of the theory has to await the advent of the

new generation of millimeter interferometers in the southern hemisphere.

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gzipped postscript (190 kb) - http://www.astro.su.se/~rene/rl_private/pp.html

Proper motions of the inner condensations in the HH 80-81 thermal radio jet

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We report multi-epoch interferometric radio observations of the IRAS source 18162−2048 that drives the thermal radio jet in the HH 80-81/GGD 27 complex. Our main goal was to follow the proper motion and flux density decay of the two inner young jet condensations N4 and S4, previously discovered by Martí et al. (1995), on their way out from the driving source. The tangential velocity estimated for the condensations amounts to ~60 mas yr^{-1}, equivalent to ~ 500 km s^{-1} at the distance of the complex. The brightness decay can be fitted by a power law of the time elapsed since ejection, yielding power law exponents of about −2 and −3 for the northern and southern condensations, respectively. We also discuss our observations in the context of simple biconical jet models, suggesting that both condensations are consistent with being relatively weak density enhancements in the otherwise steady jet flow. Their fading in brightness seems to be in agreement with the density decay expected in a freely expanding jet.

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Infrared spectrum of the massive protostar Orion-KL IRc2 revealed in reflection

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The infrared object IRc2 [1] in the Orion-KL star forming region is believed to contain a very young massive star [2]. However, its nature and evolutionary status remain unclear because it has been hidden from observers' view by the dense disklike envelope of gas and dust. Here we report the first spectroscopy of its 2-μm light that escapes to the polar directions of the disk and then is reflected toward us. The spectrum reveals absorption lines of neutral metallic atoms and CO, indicating that a significant part of the light originates from gas at $T_{\rm eff} \approx 4500\,\mathrm{K}$. If it represents the photosphere of an accreting protostar, its radius should be as large as $\geq 300\,R_\odot$. Such a large radius cannot be attained with the modest accretion rates commonly adopted in theories of massive star formation. Alternatively, it can be the long-postulated self-luminous accretion disk around a forming star. In either case, an unexpectedly large mass accretion rate of $\sim 10^{-2}\,M_\odot\,\mathrm{yr}^{-1}$ is suggested.

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A Spatially Complete ^{13}CO $J = 1-0$ Survey of the Orion A Cloud

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We present the results of new ^{13}CO $J = 1-0$ observations of the Orion A molecular cloud made with the two 4 meter telescopes at Nagoya University. The area observed corresponding to $l \sim 208^\circ$–215° and $b \sim -20.5^\circ$–-18.0° covers a full extent of this giant molecular cloud at a $2.0'$ grid spacing with a $2.7'$ beam. The present observations provide a first complete coverage of the cloud in ^{13}CO with a reasonably high angular resolution relative to the cloud size. In addition, a high velocity resolution of 0.1 km s^{-1} allowed us to resolve velocity components of the ^{13}CO emission. The molecular distribution is highly elongated along the galactic plane and is filamentary, as is consistent with previous molecular maps. The total molecular mass of the cloud is estimated to be $\sim 5.4 \times 10^4$ M$_\odot$. By using the velocity channel maps every 0.5 km s^{-1}, thirty-nine individual filamentary components have been identified and their basic physical quantities have been estimated. Their typical values are; 4.8 pc in length; 1.4 pc in width; and 660 M$_\odot$ in mass. We also found that these filamentary components are nearly in virial equilibrium.

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Optical and X-ray monitoring, Doppler imaging, and space motion of the young star Par 1724 in Orion

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We present a detailed study of the young T Tauri star Par 1724, located 15 arc min north of the Trapezium cluster in Orion. Our extensive VRI photometric measurements confirm the rotational period to be 5.7 days. Repeated high-resolution spectra show variability in the radial velocity with the same period. A Doppler imaging analysis based on high-S/N high-resolution spectra yields an image showing a pronounced dark feature (spot) at relatively low latitude, which is responsible for most or all of the observed variability. Our high-resolution spectra yield a rotational velocity of $v \cdot \sin i \simeq 71$ km s^{-1}, a surface gravity of $\log g \simeq 3$, and a mean heliocentric radial velocity of ~ 23 km s^{-1}, the latter being consistent with membership to the Orion association. The equivalent width of the lithium 6708Å line is variable, consistent with rotational modulation. The line is stronger when the spot is on the front side; the lithium abundance observed when the spot is on the back side is consistent with the primordial value. Many ROSAT X-ray observations show that Par 1724 is a strong and variable X-ray source. It has shown one of the most powerful X-ray flares. Our deep infrared imaging at high spatial resolution reveals no physically bound visual companions down to ~ 1 arc sec separations and a magnitude difference up to $\Delta R = 7$ mag, and also no companion down to ~ 0.13 arc sec with $\Delta K = 2.5$ mag. We also present the spectral energy distribution of Par 1724 and show that it does not display infrared excess. We estimate the bolometric luminosity to be ~ 49 $L_\odot$, the spectral type to be K0, and the radius to be ~ 9 $R_\odot$. Although Par 1724 appears to have lost all its circumstellar material, its bolometric luminosity places it very close to the stellar birth-line at an age of only $\sim 2 \cdot 10^5$ years, with a mass of ~ 3 $M_\odot$. According to its present location and 3D space motion (~ 20 km s^{-1} to the north relative to the cluster), Par 1724 may have been ejected from the Trapezium $\sim 10^5$ yrs ago. We cannot rule out that a close companion is responsible for part of the radial velocity variation, but such a close pair might still have been ejected together depending on the encounter dynamics. Par 1724 appears to be a very young, weak-line run-away T Tauri star moving north relative to the Trapezium, but sharing the Orion radial velocity.

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Low Mass Clumps in TMC-1: Scaling Laws in the Small Scale Regime

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We present new observational data on the small scale structure of the Taurus Molecular Cloud 1 (TMC-1) in the regime of 0.02 – 0.04 pc and 0.04 – 0.6 $M_\odot$. Our analysis is based on high resolution, high signal-to-noise, observations of an $8' \times 8'$ area centered on the "cyanopolyyne peak" in the SE part of the TMC-1 ridge. The observations were made in the CCS 22 GHz and 45 GHz transitions using NASA's Deep Space Network 70-m and 34-m telescopes at the Goldstone facility. The CCS emission in this region originates in three narrow components centered on LSR velocities of ~5.7, 5.9, and 6.1 km s^{-1}. These components each represent a separate cylindrical feature elongated along the ridge. Among the three velocity components we identified a total of 45 clumps with a typical CCS column density of $\sim$ few $\times 10^{13}$ cm^{-2}, an H_2 density of $\sim$ few $\times 10^4$ cm^{-3}, and a mass in the range of 0.04 to 0.6 $M_\odot$. The statistical properties of these small scale clumps are compared with those of the larger "NH_3 cores" in cold clouds and "CS cores" in the hotter Orion region. The CCS clumps in TMC-1 are found to conform to the Larson's scaling laws (relating observed linewidth to clump size) derived from the larger cores down to the small scale regime (0.02 pc and 0.04 $M_\odot$). These clumps represent a regime where microturbulence is small, amounting to ~10% of the thermal pressure inside a clump. Of the 45 clumps, only five appear to be gravitationally unstable to collapse. All unbound clumps have masses < 0.2 $M_\odot$ while bound clumps have masses in the range 0.15 – 0.6 $M_\odot$. The 6.1 km s^{-1} component contains all the gravitationally unstable clumps and is the most likel y site for future star formation.

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Preprints available at: /pub/tmc1.preprint.ps.Z anonymous ftp site on nimba.jpl.nasa.gov

ISOCAM images of the 'elephant trunks' in M 16

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We have used ISOCAM to obtain images of the 'elephant trunks' in the M 16 'Eagle nebula' in the two broadband filters LW2 (5−8.5 μm) and LW3 (12−18 μm). These pillars are clearly seen in both our filters, their emission has a colour temperature in the range 250−320 K.

We have also detected bright extended emission in the LW3 filter, in an area outside the 'elephant trunks', and with no LW2 counterpart.

We report the detection of a deeply embedded source, presumably connected with M16-E31, which we identify as a YSO. However, to our levels of angular resolution and sensitivity we cannot, in general, correlate discrete sources with the EGGs discovered by the HST. Our observations are consistent with a relatively low level of ongoing low-mass star formation, a fact which may be related to disk disruption taking place at early times in M 16.

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Paper is available in PDF format at URL http://astro.estec.esa.nl/Pubs/pubs.html

A Numerical Simulation of a Wind/Molecular Clump Interaction

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It has been pointed out in the past that it is impossible to accelerate molecular material to velocities ≥ 25 km s^{-1} with

gasdynamic shocks without dissociating the gas. Because of this, it has been argued that observations of molecular emission with radial velocities $\sim$ 20-100 km s^{-1} imply the presence of "C-shocks" (which have much lower post-shock temperatures, and therefore do not dissociate the gas) and the existence of strong ($\sim$ 10-100 μG) magnetic fields.

In this paper, we discuss an alternative mechanism for accelerating molecular material to high velocities : a high velocity, low density wind drives a non-dissociative shock (with shock velocity $v_{cs} \leq 25$ km s^{-1}) into a high density, molecular clump. Once this shock wave has gone through the clump, the molecular material is moving at a velocity $\sim v_{cs}$ and has a gas pressure approximately equal to the ram pressure of the impinging wind. The compressed molecular clump can now be accelerated directly by the ram pressure of the wind (without the passage of further shocks through the molecular material), and will eventually move at the wind velocity.

This mechanism has been previously invoked to explain high velocity molecular emission. However, numerical simulations have shown that a wind/clump interaction leads to the fragmentation of the clump before it can be accelerated to large velocities. In our numerical simulation (which includes an approximate treatment of the relevant microphysics) we find that the fragments that are produced are still largely molecular, and that they are rapidly accelerated to velocities comparable to the wind velocity. We therefore conclude that a wind/molecular clump interaction is indeed a valid mechanism for producing high velocity molecular features.

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Working Surfaces in Radiative, Non-Top Hat Jets

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Most models of radiative jets have been computed for the special case of a top hat initial cross section. This paper discusses the dynamics of both leading and internal working surfaces in jets with more general initial cross sections, based on both an analytic, "thin shell" model, and on a full numerical simulation. We find that a non-top hat cross section for the jet ram pressure first leads to a strong curvature of the working surface shocks, and at longer timescales to the formation of a warm, dense "nose cone". These results have interesting implications for comparisons between radiative jet models and observations of Herbig-Haro objects.

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PP13S, a young, low-mass FU Orionis-type pre-main sequence star

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We present near-IR imaging and spectroscopy, together with sub-mm/mm photometry and ^{12}CO molecular line maps of the cometary nebula PP13S. Previous models have been unable to resolve whether PP13S is a young, pre-main sequence star or an old, evolved object. Our new observations prove conclusively that PP13S is a young stellar object with a luminosity of $\sim$30 L$_\odot$ and an accretion disk with an inclination of $\sim 40^\circ$. It has a ^{12}CO J=2–1 outflow, strong and broadened CO overtone band absorption, and vibrationally excited H_2 emission. We conclude that PP13S has all the characteristics of an FU Orionis-type star, and although no outburst has been observed, we suggest that PP13S should be added to the list of FUor pre-main sequence stars. Our study also includes PP13N, which we resolve into a young double star system.

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Preprint at http://www.not.iac.es/~caa/caa_papers.html

Modified Gas/grain Chemical Models

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The rate equation approach to the chemistry occurring on grain surfaces in interstellar clouds has been criticized for not taking the discrete nature of grains into account. Indeed, investigations of simple models show that results obtained from rate equations can be significantly different from results obtained by a Monte Carlo procedure. Some modifications of the rate equations have been proposed which have the effect of eliminating most of the differences with the Monte Carlo procedure for simplified models of interstellar clouds at temperatures of 10 K and slightly above.

In this study we investigate the use of the modified rate equations in more realistic chemical models of dark interstellar clouds with complex gas/grain interactions. Our results show some discrepancies between the results of models with unmodified and modified rate equations; these discrepancies are highly dependent, however, on the initial form of hydrogen chosen. If the initial form is mainly molecular, at early stages of cloud evolution there are some significant differences in calculated molecular abundances on grains but at late times the two sets of results tend to converge for the main components of the grain mantles. If the initial form is atomic hydrogen, there are essentially no differences in results between models based on the unmodified rate equations and those based on the modified rate equations, except for the abundances on grains of some minor complex molecules. Thus, the major results of previous gas-grain models of cold, dark interstellar clouds remain at least partially intact.

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ASCA Detection of a Super-hot 100 million K X-ray Flare on the Weak-lined T Tauri Star V773 Tauri

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We present results of a ≈40 ksec ASCA observation of the active weak-lined T Tauri star V773 Tau (= HD 283447) and the surrounding Barnard 209 dark cloud obtained in February 1995. During this observation V773 Tau exhibited a dramatic X-ray flare with the X-ray count rate increasing rapidly by a factor of ∼20, then decreasing exponentially with an e-folding time-scale of ≈2.3 hours. The peak flare luminosity was at least $\sim 10^{33}$ ergs s^{-1} (0.7 – 10 keV; distance = 150 pc), which is among the highest X-ray luminosities observed to date for T Tauri stars. The total energy release was $\sim 10^{37}$ ergs.

However, the most spectacular aspect of this flare was its temperature, which reached a maximum value of at least 100 million K. Spectral fits near flare maximum give a temperature of ∼10 keV, which slowly declined to a value ∼6 keV at the end of the observation. These temperature measurements are based on high signal-to-noise spectra, and provide the first unambiguous evidence for super-hot flaring plasma at temperatures of $\sim 10^8$ K in T Tauri stars. A simple cooling loop model gives electron densities that are similar to those of solar flares but requires loop sizes that are comparable to or larger than the star itself.

The flare showed other interesting behavior, including a high (and possibly variable) absorption column density $N_H = 4 \times 10^{22}$ cm^{-2}, and an apparent increase in the global metal abundance during the flare.

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ftp://ftp-cr.scphys.kyoto-u.ac.jp/pub/crmember/tsuboi/

Large Scale Structure, Kinematics, and Heating of the Orion Ridge. I. VLA NH3 (1,1) and (2,2) Multi-Field Mosaics

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We present high resolution VLA mosaics of 18 adjacent fields in OMC-1 covering an $8' \times 4'$ (1.2×0.6 pc) region surrounding the Orion-KL core. The NH_3 (J,K) = (1,1) and (2,2) inversion transitions were observed; the resulting maps were produced with both high spectral (0.3 km s^{-1}) and high angular ($8''$) resolution. Both linear and nonlinear (maximum entropy method) techniques were employed to create the mosaics; we compare the challenges and results of each method. The complex effects of chemical excitation are discussed. We find extended clumpy filaments throughout the 0.5 parsec region extending to the north and west from Orion-KL. The structure of filaments composed of chains of condensations appears to be hierarchical in OMC-1, as it is found on several scales. The filaments are separated into at least two major velocity components that appear to overlap in the central Orion-KL core region, suggesting interaction between cloud components as a possible triggering mechanism for the active high-mass star formation occuring there. The overlapping nature of the velocity components complicates simple global rotation models for OMC-1. The filaments appear to be fragmented into beadlike chains of dense clumps, which may show a continuing pattern of structural instabilities and star formation in the region. Some of these fragments may be sites, or future sites, of young stars. Some have very large velocity gradients and may be collapsing cores that have not yet shed their angular momentum. We also present a high resolution NH_3 (2,2)/(1,1) ratio map of the region, representing the temperature. Striking patterns of heating are apparent: around the central Orion-KL core, strong heating is found in a patchy ring surrounding the Orion bipolar outflow source, possibly delineating the paths by which the outflowing gas exits the central dense region and heats the gas along the way. Heating is evident along the edges of the filaments and clumps that face the path of the outflow, showing direct impact of outflows and radiation on the molecular environment. Other clumps along the filaments show slight temperature enhancements along their outer sheaths, which may be the result of radiation from external stars penetrating the clumpy medium and heating the core sheaths. The complex combination presented here of filaments, fragmentation, kinematical interaction, and heating along the OMC-1 ridge provides evidence for extensive and long-range interaction between a core of high mass star formation and its surrounding cloud environment.

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Preprints available at http://www.cv.nrao.edu/~jwiseman/ or by e-mail request

A Head-Tail Structured Molecular Cloud and a CO Outflow Associated with IRAS 22103+5828 in S134

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We carried out ^{12}CO, ^{13}CO, and C^{18}O (J = 1–0) observations toward IRAS 22103+5828 in the HII region S134 with the 4 m telescope at Nagoya University and the 45 m telescope at Nobeyama Radio Observatory. We found a molecular cloud and a dense core around the *IRAS* point source. The molecular cloud is elongated, consisting of a dense "head" and a diffuse extended "tail," with the head pointing toward the exciting star of the HII region, λ Cep. The cloud shows a velocity gradient of ~ 0.2 km s^{-1} pc^{-1} along the major axis. A molecular outflow has been discovered at the position of the *IRAS* point source.

The facts that (1) the head-tail structure and the velocity gradient of the molecular cloud, (2) the presence of the dense core and the molecular outflow, and (3) the high ratio of the *IRAS* luminosity to the cloud mass strongly imply that IRAS 22103+5828 formed in the cloud associated with S134. A possibility is suggested that the rocket effect may

be the major mechanism causing the observed velocity gradient of the quiescent molecular cloud.

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http://www.a.phys.nagoya-u.ac.jp/~yonekura/work/IRAS22103/

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

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Dissertation Abstracts

A Study of the Dynamical Signatures of Star Formation

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A multi-pronged study aimed at disentangling the kinematical signatures of the earliest stages of star formation is presented. Radiative transfer calculations of millimeter and submillimeter molecular line emission from fully three-dimensional models of protostars are reported. These models are compared with detailed submillimeter molecular line observations of dynamical motions towards seven Class 0 protostellar objects.

The radiative transfer calculations are performed for two classes of protostellar collapse solutions: (1) "self-consistent", nonspherical, hydrodynamic, collapsing, rotating protostellar systems (Boss 1993); (2) parameterized, semi-analytic, rotating collapse solutions of Terebey, Shu and Cassen (1984). The morphology of the gas and dust emission is found to be a strong function of collapse time and angular resolution. From model centroid velocity maps, a distinctive new infall signature called the "blue-bulge" infall signature is derived. The blue-bulge infall signature can be observed in the centroid velocity maps of protostellar objects when infall dominates over rotation. This infall signature can be detected under a wide variety of source conditions, and should be easily observable using single-dish submillimeter telescopes. At high angular resolutions, models with moderate to high rotational rates exhibit the "polar blue-bulge" - a centroid velocity signature of underlying Keplerian rotation in an embedded cloud core. Submillimeter transitions of HCO+ and CS are found to be better than millimeter transitions in detecting infall, especially at early collapse times.

Using new submillimeter observations in CS and HCO+ towards IRAS 16293-2422, the first detection of the "blue-bulge" signature towards a protostellar object is presented. The mass accretion rate through the infall region appears consistent with an inside-out collapse model for the source. Using new submillimeter HCO+ and CO observations, a detailed study was performed of six other nearby Class 0 objects. The blue-bulge signature of infall is detected in five sources. Among these, SMM4 and B335 are known infall candidates. VLA 1623, L483 and L1262 are new sources for which evidence for infall is derived in this work. SM1N, which does not exhibit a blue-bulge appears to be a pre-protostellar object. A low luminosity bipolar outflow was detected toward SM1N, suggesting that it may be in an extremely early stage of collapse. Of the six sources, only three, SMM4, B335 and L1262 exhibited the classic blue asymmetric line profile signature of infall, suggesting that the blue-bulge signature is more robust in detecting infall than traditional line profile techniques. Evolutionary trends are seen between observationally obtainable source parameters and model derived timescales for the Class 0 sources presented in this work. Such a study when extended to a larger sample of YSOs will help in the understanding of the evolution of YSOs from the embedded protostellar stage to revealed pre-main-sequence objects.

The Physics of the Interstellar Medium

by J. E. Dyson & D. A. Williams

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