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Abstracts of recently accepted papers

Deuterium Fractionation in Protoplanetary Disks

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We investigate the chemistry of deuterium-bearing molecules in outer regions of protoplanetary disks, where comets may form. We find that molecules formed in the disk have higher D/H ratios (by which we mean abundance ratios between the singly deuterated species and the normal species) than the elemental D/H ratio in protosolar abundance, which is consistent with observations of recent comets. Despite the higher densities in protoplanetary disks, deuterium fractionation occurs in a similar way as in molecular clouds; because of the differences in zero-point energies and the existence of rapid ion-molecule isotopic exchange reactions, species such as H_3^+ have high D/H ratios, which propagate to other molecules via gas-phase chemical reactions.

Our results depend on a variety of factors such as the ionization rate and the temperature of the disk, which is somewhat uncertain due to possible variations in stellar luminosity and to the existence of accretion shocks. In order to reproduce the observed cometary values of DCN/HCN and HDO/H₂O, a lower ionization rate ($\sim 10^{-18} \text{ s}^{-1}$) than is “standard” in molecular clouds is more favorable. The calculated DCN/HCN ratio also depends on whether the products assumed for the grain surface recombination reaction between HCO^+ and electrons are dissociative or not.

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Shocked Molecular Gas Associated with the Supernova Remnant W28

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We report mapping observations of the CO $J = 3-2$ and CO $J = 1-0$ lines toward supernova remnant (SNR) W28, which is supposed to be an EGRET γ -ray source. The broad CO line emission (maximum linewidth reaches 70 km s^{-1}), which suggests the interaction between the molecular cloud and W28 SNR, was detected. Moreover, the distribution of the unshocked and shocked gas is clearly resolved. The distribution of the shocked gas is similar to that of the radio continuum emission, and tends to be stronger along the radio continuum ridge. The unshocked gas is displaced by 0.4–1.0 pc outward with respect to the shocked gas. The spatial relationship between shocked and unshocked gas has been made clear for the first time for the SNR-cloud interaction. All the known OH maser spots are located along the filament of the shocked gas. These facts convincingly indicate that W28 SNR interacts with molecular cloud.

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<http://www.nro.nao.ac.jp/~eiko/nroreport/>

Turbulent Flow-Driven Molecular Cloud Formation: A Solution to the Post-T Tauri Problem?

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We suggest that molecular clouds can be formed on short time scales by compressions from large scale streams in the interstellar medium (ISM). In particular, we argue that the Taurus-Auriga complex, with filaments of $10\text{-}20\text{ pc} \times 2\text{-}5\text{ pc}$, most have been formed by H I flows in $\leq 3\text{ Myr}$, explaining the absence of post-T Tauri stars in the region with ages $\geq 3\text{ Myr}$. Observations in the 21 cm line of the H I “halos” around the Taurus molecular gas show many features (broad asymmetric profiles, velocity shifts of H I relative to ^{12}CO) predicted by our MHD numerical simulations, in which large-scale H I streams collide to produce dense filamentary structures. This rapid evolution is possible because the H I flows producing and disrupting the cloud have much higher velocities ($5\text{-}10\text{ km s}^{-1}$) than present in the molecular gas resulting from the colliding flows. The simulations suggest that such flows can occur from the global ISM turbulence without requiring a single triggering event such as a SN explosion.

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A near infrared study of the HII/photodissociation region DR 18 in Cygnus

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Near infrared observations of DR 18, a HII region in the Cygnus X molecular complex, are presented in this paper. These observations reveal DR 18 as an arc-shaped nebula in the $2.2\text{ }\mu\text{m}$ region, with a central star of $V = 15.6$ obscured by $A_V \simeq 8$ magnitudes. Visible and near-infrared spectroscopy and photometry indicate a spectral type around B0.5V for this star, while a near-infrared color-color diagram of the stars in the area shows that the central star is the most luminous one of a loose aggregate. Analysis of the narrow band imaging in the K band suggests that the arc nebulosity is principally due to emission by small grains, heated by the central star, in a photodissociation region. We interpret the arc nebula as the interface between a molecular cloud that is being eroded by the central star and the resulting HII region. Using published models of photodissociation regions, we estimate the density in the arc nebula to be a few times 10^3 cm^{-3} . We briefly discuss the possible relation of the structures observed in the near infrared with the source IRAS 20333+4102, which has been included in several far infrared and radio studies of the area. We conclude that IRAS 20333+4102 is not directly related to any of the structures that we describe here, and could be an intermediate mass protostar embedded deeper in the molecular cloud.

The emission associated to ionized gas in DR 18 has a morphology fairly different from that of the arc nebula, being brighter near the position of the central star. A crescent-shaped peak is observed beside the central star and facing the arc nebula, suggesting an interaction between a stream of ionized gas from the nebula and the wind from the central star. We present two dimensional gas dynamical simulations which successfully reproduce such gas stream, the bow shock ahead of the central star, and the overall appearance of the nebula. An essential component of our model is the existence of an outward-decreasing density stratification in the cloud being eroded, as is commonly observed in dense molecular clumps.

The simple geometry of the nebula and the observability of the central star at short wavelengths make the derivation of the physical conditions of the region and the modeling of its dynamical evolution comparatively easier than in other, similar regions. DR 18 thus provides a good case study of several features associated to the interaction of an early B star with a molecular cloud.

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

Three-Dimensional Simulations of Jet/Cloud Interactions: Structure and Kinematics of the Deflected Jets

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We report the results of three-dimensional smoothed particle hydrodynamics simulations of interactions of overdense, radiatively cooling and adiabatic jets with dense, compact clouds in frontal and off-axis collisions. Calculated for a set of parameters which are particularly appropriate to protostellar jets, our results indicate that the interaction produces important transient and permanent effects in the jet morphology.

In off-axis interactions, the deflected beam initially describes a C-shaped trajectory around the curved jet/cloud contact discontinuity but the deflection angle tends to decrease with time as the beam slowly penetrates the cloud. Later, when the jet has penetrated most of the cloud extension, the deflected beam fades and the jet resumes its original direction of propagation. During the interaction, a weak chain of internal knots develops along the deflected beam and the velocity field initially has a complex structure that later evolves to a more uniform distribution. The average velocity of the deflected beam is consistent with the predicted value given by $v'_j \simeq v_j \cos \theta$ (where θ is the deflection angle, and v_j is the velocity of the incident beam). The impact also decreases the beam collimation. Applied to the context of the protostellar jets, this morphology and kinematics found for the deflected beam is very similar to that observed in some candidate systems like the HH 110 jet which has been previously proposed to be the deflected part of the HH270 jet. Our simulations also reveal the formation of a *head – neck* bright structure at the region of impact which resembles the morphology of the HH 110 knot A, located in the apex of the HH 110 jet where the deflection is believed to occur. All these similarities strongly support the proposed jet/cloud interaction interpretation for this system. The fact that the deflection angles derived from the simulations are smaller than that observed and the fact that the jet/cloud interaction is still taking place indicate that the interacting cloud in that system must have a radius $R_c \gg R_j$, where R_j is the jet radius, as previously suggested, and a density ratio between the jet and the cloud $\beta^2 = n_j/n_c \leq 10^{-2}$.

Due to the small size of the clouds [with radius $R_c \simeq (1 - 2)R_j$], the interactions examined here are very transient (with lifetimes of few ~ 10 to ~ 100 yr which are \ll than the typical dynamical lifetimes of the protostellar outflows, $\tau \geq 10^4$ yr). Nonetheless, they leave important signatures in the surviving outflow. The left-overs of the cloud and the knots that are produced in the deflected beam are deposited into the working surface and contribute to enrich the knotty pattern commonly observed in HH objects behind the bow shocks of protostellar jets. Also, the collision may partially destroy the shell at the head producing remarkable asymmetries in the head region. A jet undergoing many transient interactions with compact clumps along its propagation and lifetime may inject a considerable amount of shocked jet material sideways into the surrounding ambient medium and this process may provide a powerful tool for momentum transfer and turbulent mixing with the ambient medium.

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preprint: astro-ph/9904145; higher resolution figures at: <http://www.iagusp.usp.br/~dalpino/jet-cloud/>

A burst of outflows from the Serpens cloud core: wide-field submillimetre continuum, CO J=2-1 and optical observations.

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Wide-field mapping of Serpens in submillimetre continuum emission and CO J=2-1 line emission are here complemented by optical imaging in [SII] $\lambda\lambda 6716, 6731$ line emission. Analysis of the $450\ \mu\text{m}$ and $850\ \mu\text{m}$ continuum data show at least 10 separate sources, along with fainter diffuse background emission and filaments extending to the south and east of the core. These filaments describe “cavity-like” structures that may have been shaped by the numerous outflows in the region. The dust opacity index, β , derived for the identifiable compact sources is of the order of 1.0 ± 0.2 , with dust temperatures in excess of 20 K. This value of β is somewhat lower than typical Class I YSOs; we suggest that the Serpens sources may be “warm”, late Class 0 or early Class I objects.

With the combined CO and optical data we also examine, on large scales, the outflows driven by the embedded sources in Serpens. In addition to a number of new Herbig-Haro flows (here denoted HH 455 – 460), a number of high-velocity CO lobes are observed; these extend radially outwards from the cluster of submillimetre sources in the core. A close association between the optical and molecular flows is also identified. The data suggest that many of the submillimetre sources power outflows. Collectively, the outflows traced in CO support the widely-recognised correlation between source bolometric luminosity and outflow power, and infer a dynamical age for the whole protostellar cluster of $\sim 3 \times 10^4$ years. Notably, this is roughly equal to the proposed duration of the “Class 0” stage in protostellar evolution.

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Preprints available from <http://www.jach.hawaii.edu/~cdavis/papers.html>

Spectroscopy of Pre-Main Sequence candidates of spectral type AF in the Young Galactic Cluster IC 4996

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We present the results of a spectroscopic analysis of the Pre-Main Sequence (PMS) candidates in IC 4996, proposed by Delgado et al. (1998). Spectral types and heliocentric radial velocities are calculated for 16 stars in the field observed by these authors, 13 of them located in the region of the Color-Magnitude diagram where their proposed PMS stars are located. The estimated heliocentric radial velocity of the cluster is centered around -12 ± 5 km/sec. From the radial velocity distribution, 6 stars are rejected as cluster members, one of them showing spectral features characteristic of an Am star. The remaining 10 stars are confirmed as cluster members: three B-type stars, and 7 PMS stars of spectral types A4-F0 (6 stars), and early G (1 star). One of the proposed PMS members clearly shows radial velocity and spectral type variations, as well as relatively broad H α absorption. The G-type cluster member is a weak line T-Tauri star with a strong LiI 6708 absorption ($W_\lambda(\text{LiI}) \simeq 0.26 \text{ \AA}$). These results strongly support the presence in the cluster of a populated sequence of PMS stars of AF spectral type.

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Measurements of the J=2-1 Lines of CS and C¹⁸O toward the Star-Forming Region W 49 A North

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Observations of the W 49 A North star forming region in the J=2–1 line of CS have been made with the BIMA

array with an angular resolution of $4.6'' \times 3.8''$; complementary observations in the $J=2-1$ line of $C^{18}O$ and $J=3-2$ line of $C^{34}S$ were made with the IRAM 30 meter telescope with angular resolutions of $12''$ and $17''$ respectively. The molecular complex is elongated along a diagonal from northeast to southwest. The position-velocity diagrams for CS convolved to $12''$ resemble those of $C^{18}O$ and the $J=5-4$ line of $C^{34}S$ (from Serabyn et al. 1993). There is a change in velocity along the major axis of the molecular complex. Most spectra towards W 49 A North show two main velocity components whose relative intensities vary with position along the major axis of the molecular complex.

At the higher resolution of $\sim 4''$, absorption of the continuum emission at 3 mm by CS is clearly observed. The apparent velocity gradient is seen to be part of a “C”-shaped distribution in the CS position-velocity image. Furthermore, as is found in the $J=1-0$ HCO^+ data by Welch et al. (1987), the optically thick CS $J=2-1$ line exhibits an inverse P-Cygni profile towards HII region **G**. These two characteristics of the CS data lend support to the global collapse model (Welch et al. 1987). The high resolution CS profiles in the central region all show varying degrees of absorption. At lower resolution the surrounding CS emission fills in much of the absorption and the inverse P-Cygni shape disappears.

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Preprints are available at URL: <http://www.astro.uiuc.edu/department/preprints/hdickel/>

A WIYN Lithium Survey for Young Stars in the λ Orionis Star-Forming Region

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We have found 72 pre-main sequence (PMS) stars near the center of the λ Orionis star-forming region by spectroscopically testing a magnitude-limited sample for the presence of lithium $\lambda 6708 \text{ \AA}$ absorption, a diagnostic of youth. All of these stars show large lithium equivalent widths and radial velocities consistent with Orion membership, yet only two were discovered previously via $H\alpha$ or X-ray surveys. Comparison with PMS evolutionary tracks show that the low-mass star formation did not begin prior to the initiation of high-mass star formation 5-7 Myr ago. However, the subsequent detailed star-formation history is model-dependent. Baraffe et al. (1998) isochrones imply that high- and low-mass stars began to form together 5-7 Myr ago, with the low-mass stellar formation ceasing abruptly 1 Myr ago. On the other hand, D’Antona & Mazzitelli (1998) isochrones indicate a narrow spread of PMS ages which suggest a burst of low-mass star formation 1-2 Myr ago. Furthermore, kinematic arguments require that the parent molecular cloud gravitationally bound the stars together until recently, yet at present the requisite gas mass is not visible. This leads us to conjecture that both the high- and low-mass stars were in a tightly bound cluster until a supernova blast about 1 Myr ago disrupted the parent cloud. This supernova also impacted on the PMS formation process by either (1) ceasing formation through removal of the gas supply or (2) triggering star births via cloud compression, depending on choice of stellar evolution models. Finally, we find that despite their youth only 4 of the 72 PMS stars have T Tauri-like $H\alpha$ emission, suggesting the absence of accretion disks. We conjecture that this may be the result of photoevaporation of the disks while the low-mass stars were in much closer proximity to the OB stars prior to becoming gravitationally unbound.

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<http://www.astro.wisc.edu/~dolan/thesis/>

A Prediction of Brown Dwarfs in Ultracold Molecular Gas

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A recent model for the stellar initial mass function (IMF), in which the stellar masses are randomly sampled down to the thermal Jeans mass from hierarchically structured pre-stellar clouds, predicts that regions of ultra-cold CO gas, such as those recently found in nearby galaxies by Allen and collaborators, should make an abundance of Brown Dwarfs with relatively few normal stars. This result comes from the low value of the thermal Jeans mass, which scales as $M_J \propto T^2/P^{1/2}$ for temperature T and pressure P , considering that the hierarchical cloud model always gives the

Salpeter IMF slope above this lower mass limit. The ultracold CO clouds in the inner disk of M31 have $T \sim 3\text{K}$ and pressures that are probably $10\times$ higher than in the solar neighborhood. This gives a mass at the peak of the IMF equal to $0.01 M_{\odot}$, well below the Brown Dwarf limit of $0.08 M_{\odot}$. Using a functional approximation to the IMF given by $(1 - e^{-[M/M_J]^2}) M^{-1.35} d\log M$ for $M > M_J$, which fits the local IMF for the expected value of $M_J \sim 0.3 M_{\odot}$, an IMF with $M_J = 0.01 M_{\odot}$ in M31 has 50% of the mass and 90% of the objects below the Brown Dwarf limit. The brightest of the Brown Dwarfs in M31 should have an apparent, extinction-corrected K-band magnitude of ~ 21 mag in their pre-main sequence phase. For typical star-formation efficiencies of $\leq 10\%$, Brown Dwarfs and any associated stars up to $\sim 2.5 M_{\odot}$ should not heat the gas noticeably, but if the IMF continues up to arbitrarily high masses, then the star formation efficiency has to be $\leq 10^{-4}$ to avoid heating from massive stars.

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High energy products in young stellar objects

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Observational studies of low-mass stars during their early stages of evolution, from protostars through the zero-age main sequence, show highly elevated levels of magnetic activity. These include strong fields covering much of the stellar surface and powerful magnetic reconnection flares seen in the X-ray and radio bands. The flaring may occur in the stellar magnetosphere, at the star-disk interface, or above the circumstellar disk. Ionization from the resulting high energy radiation may have important effects on the astrophysics of the disk, such as promotion of accretion and coupling to outflows, and on the surrounding interstellar medium. The bombardment of solids in the solar nebula by flare shocks and energetic particles may account for various properties of meteorites, such as chondrule melting and spallogenic isotopes. X-ray surveys also improve our samples of young stars, particularly in the weak-lined T Tauri phase after disks have dissipated, with implications for our understanding of star formation in the solar neighborhood.

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Preprints are available by anonymous-ftp at ftp.astro.psu.edu/pub/edf/araa. File araa_pp.ps contains the text and araa_figs.ps contains the figures.

VLA Observations of H₂O Masers in the Class 0 Protostar S106 FIR: Evidence for a 10 AU-Scale Accelerating Jet-like Flow

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We conducted VLA observations at $0.''06$ resolution of the 22 GHz water masers toward the Class 0 source S106 FIR ($d = 600$ pc; $15''$ west of S106-IRS4) on two epochs separated by ~ 3 months. Two compact clusters of the maser spots were found in the center of the submillimeter core of S106 FIR. The separation of the clusters was ~ 80 mas (48 AU) along P.A. = 70° and the size of each cluster was ~ 20 mas \times 10 mas. The western cluster, which had three maser components, was 8.0 km s^{-1} blueshifted and the eastern cluster, which has a single component, was 7.0 km s^{-1} redshifted with respect to the ambient cloud velocity. Each component was composed of a few spatially localized maser spots and was aligned on a line connecting the clusters. We found relative proper motions of the components with $\approx 30 \text{ mas year}^{-1}$ (18 AU year^{-1}) along the line. In addition, a series of single-dish observations show that the

maser components drifted with a radial accelerations of $\sim 1 \text{ km s}^{-1} \text{ year}^{-1}$.

These facts indicate that the masers could be excited by a 10 AU-scale jet-like accelerating flow ejected from an assumed protostar located between the two clusters. The outflow size traced by the masers was $50 \text{ AU} \times 5 \text{ AU}$ after correction for an inclination angle of 10° which was derived from the relative proper motions and radial velocities of the maser components. The three-dimensional outflow velocity ranged from 40 to 70 km s^{-1} assuming symmetric proper motions for the blue and red components. Since no distinct CO molecular outflows have been detected so far, we suggest that S106 FIR is an extremely young protostar observed just after the onset of outflowing activity.

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<http://www.nro.nao.ac.jp/~v96aips7/paper/index.html>

Massive Stars: Their Environment and Formation

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Cloud environment is thought to play a critical role in determining the mechanism of formation of massive stars. In this contribution we review the physical characteristics of the environment around recently formed massive stars. Particular emphasis is given to recent high angular resolution observations which have improved our knowledge of the physical conditions and kinematics of compact regions of ionized gas and of dense and hot molecular cores associated with luminous O and B stars. We will show that this large body of data, gathered during the last decade, has allowed significant progress in the understanding of the physical processes that take place during the formation and early evolution of massive stars.

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<http://xxx.lanl.gov/abs/astro-ph/9907293>

Proper Motions of H₂ Jets and Variability of Young Stars in the Serpens NW Region

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We present deep H₂ 1–0 S(1) line and continuum images as well as *K*-band proper motion data on a system of emission knots in the Serpens NW region. Our data demonstrate that the jet outlined by these knots originates in “knot a” of the SMM 9 molecular clump in Serpens NW. Kinematic indications for remnants of molecular material being expelled from the star EC 37 were found. The jet associated with SMM 1 (FIRS1) was shown to indeed move in the direction suggested by its morphology. The faint star (EC 41) seen in the near infrared close to the apex of that jet is almost certainly not identical with the driving source of the outflow.

Extremely red stars, associated with some nebulosity, were found very close to the positions of the outflow sources S68 N/SMM 9 and SMM 10, suggesting that these stars found in the *K* band are identical to the objects detected at submillimeter wavelengths.

We are reporting on the photometric monitoring of the Serpens Deeply Embedded Outburst Star (DEOS), discovered in 1995, and other young stars in Serpens. After an initial steeper drop in brightness by 0.84 mag in the first 290 days after the recorded maximum, the DEOS brightness is now decreasing at a slower average rate of 0.33 mag yr^{-1} . Its spectrum has changed since the time of discovery and now shows faint indications of CO bandhead absorption.

The cometary nebula EC 53 (associated with SMM 5) shows repeated outbursts between 1994 and 1998; a periodicity of about 550 days is suggested. This Class I source is probably an EXor variable.

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Evidence for early stellar encounters in the orbital distribution of Edgeworth-Kuiper Belt objects

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We show that early stellar encounters can explain the high eccentricities and inclinations observed in the outer part ($> 42\text{AU}$) of the Edgeworth-Kuiper Belt (EKB). We consider the proto-sun as a member of a stellar aggregation that undergoes dissolution on a timescale $\sim 10^8$ yrs, such that the solar nebula experiences a flyby encounter at pericenter distance (q) on the order of 100AU . Using numerical simulations we show that a stellar encounter pumps the velocity dispersion in the young solar nebula in the outer parts. In the case of a nearly parabolic encounter with a solar-mass companion the velocity dispersion at $a \gtrsim 0.25q$ is pumped up to such an extent that collisions between planetesimals would be expected to become highly disruptive, halting further growth of planetesimals. This has the consequence that planet formation is forestalled in that region. We also find that a stellar encounter with pericenter distance $q \sim 100\text{--}200\text{AU}$ could have pumped up the velocity dispersion of EKB objects outside 42AU to the observed magnitude while preserving that inside Neptune's 3:2 mean-motion resonance (located at 39.5AU). This allows for the efficient capture of objects by the resonance during a phase of orbital migration by proto-Neptune, which we also test with simulations. We point out that such a stellar encounter generally affects the dynamical and material structure of a protoplanetary disk and the planetesimal distribution can remain imprinted with this signature over much of the main sequence lifetime of the star. In particular, our results support the notion that an analogous process has operated in some recently observed extrasolar dust disks.

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A disk census for the nearest group of young stars: Mid-infrared observations of the TW Hydrae Association

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A group of young, active stars in the vicinity of TW Hydrae has recently been identified as a possible physical association with a common origin. Given its proximity (~ 50 pc), age (~ 10 Myr) and abundance of binary systems, the TW Hya Association is ideally suited to studies of diversity and evolution of circumstellar disks. Here we present mid-infrared observations of 15 candidate members of the group, 11 of which have no previous flux measurements at wavelengths longer than $2\mu\text{m}$. We report the discovery of a possible $10\mu\text{m}$ excess in CD -33°7795, which may be due to a circumstellar disk or a faint, as yet undetected binary companion. Of the other stars, only TW Hya, HD 98800, Hen 3-600A, and HR 4796A – all of which were detected by IRAS – show excess thermal emission. Our $10\mu\text{m}$ flux measurements for the remaining members of the Association are consistent with photospheric emission, allowing us to rule out dusty inner disks. In light of these findings, we discuss the origin and age of the TW Hya Association as well as implications for disk evolution timescales.

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Far Infrared and Submillimeter Emission from Galactic and Extragalactic Photo-Dissociation Regions

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Photodissociation Region (PDR) models are computed over a wide range of physical conditions, from those appropriate to giant molecular clouds illuminated by the interstellar radiation field to the conditions experienced by circumstellar disks very close to hot massive stars. These models use the most up-to-date values of atomic and molecular data, the most current chemical rate coefficients, and the newest grain photoelectric heating rates which include treatments of small grains and large molecules. In addition, we examine the effects of metallicity and cloud extinction on the predicted line intensities. Results are presented for PDR models with densities over the range $n = 10^1 - 10^7 \text{ cm}^{-3}$ and for incident far-ultraviolet radiation fields over the range $G_0 = 10^{-0.5} - 10^{6.5}$ (where G_0 is the FUV flux in units of the local interstellar value), for metallicities $Z=1$ and 0.1 times the local Galactic value, and for a range of PDR cloud sizes. We present line strength and/or line ratio plots for a variety of useful PDR diagnostics: [C II] $158\mu\text{m}$, [O I] $63\mu\text{m}$ and $145\mu\text{m}$, [C I] $370\mu\text{m}$ and $609\mu\text{m}$, CO $J = 1 - 0$, $J = 2 - 1$, $J = 3 - 2$, $J = 6 - 5$ and $J = 15 - 14$, as well as the strength of the far-infrared continuum. These plots will be useful for the interpretation of Galactic and extragalactic far infrared and submillimeter spectra observable with the *Infrared Space Observatory*, the *Stratospheric Observatory for Infrared Astronomy*, the *Submillimeter Wave Astronomy Satellite*, the *Far Infrared and Submillimeter Telescope* and other orbital and suborbital platforms. As examples, we apply our results to ISO and ground based observations of M82, NGC 278, and the Large Magellenic Cloud. Our comparison of the conditions in M82 and NGC 278 show that both the gas density and FUV flux are enhanced in the starburst nucleus of M82 compared with the normal spiral NGC 278. We model the high [C II]/CO ratio observed in the 30 Doradus region of the LMC and find it can be explained either by lowering the average extinction through molecular clouds or by enhancing the density contrast between the atomic layers of PDR and the CO emitting cloud cores. The ratio $L[\text{CO}]/M[\text{H}_2]$ implied by the low extinction model gives cloud masses too high for gravitational stability. We therefore rule out low extinction clouds as an explanation for the high [C II]/CO ratio and instead appeal to density contrast in $A_V = 10$ clouds.

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Binary stars in young clusters: models versus observations of the Trapezium Cluster

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The frequency of low-mass pre-main sequence binary systems is significantly lower in the Trapezium Cluster than in Taurus-Auriga. We investigate if this difference can be explained through stellar encounters in dense clusters. To this effect, a range of possible models of the well observed Trapezium Cluster are calculated using Aarseth's direct N-body code, which treats binaries accurately. The results are confronted with observational constraints. The range of models include clusters in virial equilibrium, expanding clusters as a result of instantaneous mass loss, as well as collapsing clusters. In all cases the primordial binary proportion is larger than 50 per cent, with initial period distributions as observed in Taurus-Auriga and the Galactic field.

It is found that the expanding model, with an initial binary population as in the Galactic field, is most consistent with the observational constraints. This raises the possibility that the primordial group of OB stars may have expelled the cluster gas roughly 50 000 yr ago. The cluster's bulk expansion rate is thus a key observable that needs to be determined. The other models demonstrate that the rapidly decreasing binary proportion, its radial dependence and the form of the period distribution, together with structural and kinematical data, are very useful diagnostics on the

present and past dynamical state of a young cluster. In particular, kinematical cooling from the disruption of wide binaries is seen for the first time.

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A Survey for Infall Motions Toward Starless Cores. I. CS (2 – 1) and N₂H⁺ (1 – 0) Observations

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We present the first results of a survey of 220 starless cores selected primarily by their optical obscuration (Lee & Myers 1999) and observed in CS(2–1), N₂H⁺ (1–0), and C¹⁸O (1–0) using the NERO Haystack 37-m telescope. We have detected 163 out of 196 sources observed in CS, 72 out of 142 in N₂H and 30 out of 30 in C¹⁸O. In total, 69 sources were detected in both CS and N₂H⁺.

The isolated component of the N₂H⁺ (1–0) spectrum (F₁F = 01 – 12) usually shows a weak symmetric profile which is optically thin. In contrast, a significant fraction of the CS spectra show non-Gaussian shapes, which we interpret as arising from a combination of self absorption due to lower excitation gas in the core front and kinematics in the core.

The distribution of the normalized velocity difference (δV_{CS})

between the CS and N₂H⁺ peaks appears significantly skewed to the blue ($\delta V_{CS} < 0$), as was found in a similar study of dense cores with embedded young stellar objects (YSOs) (Mardones et al. 1997). The incidence of sources with blue asymmetry tends to increase as the total optical depth or the integrated intensity of the N₂H⁺ line increases. This overabundance of “blue” sources over “red” sources suggests that inward motions are a significant feature of starless cores. We identify 7 strong infall candidates and 10 probable infall candidates. Their typical inward speeds are sub-sonic, approximately 0.04 – 0.1 km s^{–1}, so they contain ‘thermal’ infall motions, unlike the faster inward speeds associated with most YSOs (Mardones et al. 1997). We discuss the importance of the choice of a consistent set of line frequencies when using the velocity shift between an optically thick and a thin line as a tracer of infall, and show how the results of the survey depend on that frequency choice.

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A magnetic scale height: the effect of toroidal magnetic fields on the thickness of accretion discs

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We consider accreting systems in which the central object interacts, via the agency of its magnetic field, with the disc that surrounds it. The disc is turbulent and, so, has a finite effective conductivity. The field sweeps across the face of the disc, thereby forming a current that is directed radially within the disc. In turn, this disc current creates a toroidal field, where the interaction between the disc current and the toroidal field produces a Lorentz force that compresses the disc. We investigate this compression which creates a *magnetic scale height* of the disc that can be much smaller than the conventional scale height. We derive an analytic expression for the magnetic scale height and apply it to fully ionized discs.

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The Energy Dissipation Rate of Supersonic, Magnetohydrodynamic Turbulence in Molecular Clouds

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Molecular clouds have broad linewidths suggesting turbulent supersonic motions in the clouds. These motions are usually invoked to explain why molecular clouds take much longer than a free-fall time to form stars. It has classically been thought that supersonic hydrodynamical turbulence would dissipate its energy quickly, but that the introduction of strong magnetic fields could maintain these motions. In a previous paper it has been shown, however, that isothermal, compressible, MHD and hydrodynamical turbulence decay at virtually the same rate, requiring that constant driving occur to maintain the observed turbulence. In this paper direct numerical computations of uniform randomly driven turbulence with the ZEUS astrophysical MHD code are used to derive the value of the energy dissipation coefficient, which is found to be

$$\dot{E}_{\text{kin}} \simeq -\eta_v m \tilde{k} v_{\text{rms}}^3,$$

with $\eta_v = 0.21/\pi$, where v_{rms} is the root-mean-square velocity in the region, E_{kin} is the total kinetic energy in the region, m is the mass of the region, and \tilde{k} is the driving wavenumber. The ratio τ of the formal decay time $E_{\text{kin}}/\dot{E}_{\text{kin}}$ of turbulence to the free-fall time of the gas can then be shown to be

$$\tau(\kappa) = \frac{\kappa}{M_{\text{rms}}} \frac{1}{4\pi\eta_v},$$

where M_{rms} is the rms Mach number, and κ is the ratio of the driving wavelength to the Jeans wavelength. It is likely that $\kappa < 1$ is required for turbulence to support gas against gravitational collapse, so the decay time will probably always be far less than the free-fall time in molecular clouds, again showing that turbulence there must be constantly and strongly driven. Finally, the typical decay time constant of the turbulence can be shown to be

$$t_0 \simeq 1.0 \mathcal{L}/v_{\text{rms}},$$

where \mathcal{L} is the driving wavelength.

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New Herbig–Haro Objects and Giant Outflows in Orion

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We present the results of a photographic and CCD imaging survey for Herbig–Haro (HH) objects in the L1630 and L1641 giant molecular clouds in Orion. The new HH flows were initially identified from a deep H α film from the recently commissioned AAO/UKST H α Survey of the southern sky. Our scanned H α and broad band R images highlight both the improved resolution of the H α survey and the excellent contrast of the H α flux with respect to the broad band R. Comparative IVN survey images allow us to distinguish between emission and reflection nebulosity. Our CCD H α , [SII], continuum and I band images confirm the presence of a parsec–scale HH flow associated with the Ori I–2 cometary globule and several parsec–scale strings of HH emission centred on the L1641–N infrared cluster. Several smaller outflows display one–sided jets. Our results indicate that for declinations south of -6° in L1641, parsec–scale flows appear to be the major force in the large–scale movement of optical dust and molecular gas.

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The Kinetic Temperature Structure within NGC2024

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An ideal molecular probe for tracing the kinetic temperature in dense molecular cloud cores should allow the temperature determination to be independent of gas density effects. The formaldehyde (H₂CO) molecule, a slightly asymmetric rotor, is just such a molecule. By using several sets of judiciously chosen H₂CO line ratios, we have reliably determined the gas kinetic temperatures of the dense gas condensations within the NGC2024 star formation region. Our measurements indicate $T_K > 40$ K toward the embedded sources FIR3-FIR7. These sources, which had previously been identified as isothermal protostars, are likely in a more evolved state.

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High-Resolution Studies of Gas and Dust around Young Intermediate-Mass Stars. II. Observations of an Additional Sample of Herbig Ae Systems

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In an earlier paper (Mannings & Sargent 1997; Paper I) we presented evidence for disks of gas and dust associated with seven Herbig Ae stars, based on high-resolution interferometric millimeter-wave observations of continuum and molecular line emission. These systems are simultaneously high-mass analogs of the approximately solar-mass T Tauri stars and the evolutionary precursors of the prototypical main-sequence debris disk sources β Pic, α Lyr and α PsA. Here, we extend the original survey to include four additional Herbig Ae systems. We have also imaged two of the sources from Paper I at higher resolution. The new data are presented and analyzed, and are combined with the results from the earlier sample to address the properties of this class of circumstellar disk. Derived disk masses are indistinguishable from the masses of T Tauri disks. Although the combined sample is small, it seems likely that disk masses are essentially uncorrelated with stellar mass for pre-main-sequence stars of spectral type A0 and later.

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2D Radiative Transfer with Transiently Heated Particles for the Circumstellar Environment of Herbig Ae/Be Stars

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We present results of self-consistent 2D radiative transfer calculations for Herbig Ae/Be stars. The emission from transiently heated particles and PAHs is included in these calculations. Special attention is paid to the influence of the model parameters on the strength of the PAH emission lines.

Our calculations show that appropriate 2D radiative transfer calculations are necessary in order to draw appropriate conclusions concerning the origin of the IR emission of Herbig Ae/Be stars and the mechanisms that may suppress the PAH emission lines. If one is concerned with the effect of accretion discs and transiently heated dust grains on

the spectral energy distributions, 1D calculations can lead to inappropriate conclusions.

Furthermore, no combination of model parameters has been found that results in undetectably weak PAH emission lines. Hence, PAH emission should always be detectable in radiation from Herbig Ae/Be disk/envelope systems if PAHs are present in these systems.

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Near-Infrared Spectroscopy of Molecular Hydrogen Emission in Four Reflection Nebulae: NGC 1333, NGC 2023, NGC 2068, and NGC 7023

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This paper presents near-infrared spectroscopy of fluorescent molecular hydrogen (H_2) emission from NGC 1333, NGC 2023, NGC 2068, and NGC 7023 and derives the physical properties of the molecular material in these reflection nebulae. These observations of NGC 2023 and NGC 7023 and the physical parameters derived for these nebulae are in good agreement with previous studies. Both NGC 1333 and NGC 2068 have no previously-published analysis of near-infrared spectra. This study reveals that the rotational-vibrational states of molecular hydrogen in NGC 1333 are populated quite differently from NGC 2023 and NGC 7023. We determine that the relatively weak UV field illuminating NGC 1333 is the primary cause of the difference. Further, the density of the emitting material in NGC 1333 is of much lower density, with $n \sim 10^2 - 10^4 \text{ cm}^{-3}$. NGC 2068 has molecular hydrogen line ratios more similar to those of NGC 7023 and NGC 2023. Model fits to this nebula show that the bright, H_2 -emitting material may have a density as high as $n \sim 10^5 \text{ cm}^{-3}$, similar to NGC 2023 and NGC 7023.

Our spectra of NGC 2023 and NGC 7023 show significant changes in both the near-infrared continuum and H_2 intensity along the slit and offsets between the peaks of the H_2 and continuum emission. These brightness changes may correspond to real changes in the density and temperatures of the emitting region, although uncertainties in the total column of emitting material along a given line of sight complicates the interpretation. The spatial difference in the peak of the H_2 and near-infrared continuum peaks in NGC 2023 and NGC 7023 shows that the near-infrared continuum is due to a material which can survive closer to the star than H_2 can.

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Velocity Field Statistics in Star-Forming Regions. I. Centroid Velocity Observations

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The probability density functions (pdfs) of molecular line centroid velocity fluctuations, and of line centroid velocity fluctuation differences at different spatial lags, are estimated for several nearby molecular clouds with active internal star formation. The data consist of over 75,000 ^{13}CO line profiles divided among twelve spatially and/or kinematically distinct regions. These regions range in size from less than to 1 more than 40pc and are all substantially supersonic, with centroid fluctuation Mach numbers ranging from about 1.5 to 7. The centroid pdfs are constructed using three different types of estimators. Although three regions (all in Mon R2) exhibit nearly Gaussian centroid pdfs, the other regions show strong evidence for non-Gaussian pdfs, often nearly exponential, with possible evidence for power law contributions in the far tails. Evidence for nearly exponential centroid pdfs in the neutral HI component of the ISM is also presented, based on older published data for optical absorption lines and HI emission and absorption lines. These strongly non-Gaussian pdfs disagree with the nearly-Gaussian behaviour found for incompressible turbulence (except possibly shear flow turbulence) and simulations of decaying mildly supersonic turbulence. Spatial images of

the largest-magnitude centroid velocity differences for the star-forming regions appear less filamentary than predicted by decay simulations dominated by vortical interactions. No evidence for the scaling of difference pdf kurtosis with Reynolds number, as found in incompressible turbulence experiments and simulations, is found. We conclude that turbulence in both star-forming molecular clouds and diffuse HI regions involves physical processes which are not adequately captured by incompressible turbulence or by mildly supersonic decay simulations. The variation with lag of the variance and kurtosis of the difference pdfs is presented as a constraint on future simulations, and we evaluate and discuss the implications of the large scale and Taylor scale Reynolds numbers for the regions studied here.

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On the stability and evolution of isolated Bok globules

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We present the results of three dimensional hydrodynamic simulations of evolving, isolated, low mass clouds and Bok globules, where the interstellar radiation field plays an important role in the chemical and thermal evolution. We consider two classes of cloud models: (i) clouds which are initially supported against gravitational collapse by thermal pressure alone; (ii) clouds that are supported by a mildly supersonic, complex internal velocity field (‘turbulence’) initially. The models are based on our earlier work with a Smoothed Particle Hydrodynamics code, but upgraded to include a larger chemical network, refined chemical and dust properties, and different boundary conditions. The chemical network predicts the abundances of several key tracers of cloud structure and evolution, including C⁺, CI, and CO.

There are two main purposes of this work. The first is to calculate the effective ‘Jeans Masses’ of isolated and externally heated clouds, under a range of initial conditions, in order to delineate the physical parameters necessary for gravitational collapse and star formation to occur. The second is to calculate density, temperature, and chemical species profiles for comparison with observations. We consider clouds with masses in the range $8 \leq M \leq 70 M_{\odot}$, radii in the range $0.34 \leq R \leq 1.8$ pc, and initial number densities in the range $50 \leq n \leq 1000 \text{ cm}^{-3}$, corresponding to low mass Bok globules. We examine the evolution of both uniform density and centrally condensed clouds, and clouds with and without a turbulent velocity field. The main results of our calculations are:

- (i). Clouds which proved to be gravitationally unstable collapsed to form cold, dense, molecular cores, surrounded by warm, thermally supported, tenuous halos in which the trace species were in ionic or atomic form.
- (ii). The evolution of the thermally supported clouds is driven in the first instance by a pressure gradient through the cloud that arises because of the attenuation of the interstellar radiation field. Subsequent thermal evolution leads to cooling of the gas which can induce gravitational instability.
- (iii). Initially turbulent clouds evolve through the dissipation of their internal kinetic energy, and then follow evolutionary paths similar to those of the thermally supported clouds. The effect of the turbulence is to delay the collapse of the clouds until the turbulence decays, which occurs on a rapid time scale through shock dissipation, and to increase the stability of the clouds models by a small amount.
- (iv) The collapsing dense cores that arise in the simulations have masses in the range $3 \lesssim M \lesssim 20 M_{\odot}$, radii in the range $0.1 \lesssim R \lesssim 0.2$ pc, and have temperatures in the range $8 \lesssim T \lesssim 12$ K. These compare closely with the observationally derived properties of Bok globule cores.
- (v) The characteristics of the collapsing, dense cores are similar to those of collapsing, isothermal spheres, since the gas evolves towards a constant temperature of 10 K before collapse ensues because of gas–dust thermal coupling.

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Hot Molecular Cores and the Formation of Massive Stars

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It has been proposed that some hot molecular cores (HMCs) harbor a young embedded massive star, which heats an infalling envelope and accretes mass at a rate high enough to “choke off” an incipient HII region. This class of HMCs would mark the youngest phase known of massive star formation. In order to test this hypothesis, we model this type of object calculating the radiative transfer through a spherically symmetric dusty envelope infalling onto a central OB star, with accretion rates from $\dot{M} = 6 \times 10^{-4}$ to $10^{-3} M_{\odot} \text{ yr}^{-1}$. The dust thermal spectrum from infrared to radio wavelengths is derived and is compared with the observed fluxes of several hot cores which may be internally heated. We find that the data are best fitted using an envelope with the density distribution resulting from the collapse of a singular logatropic sphere, instead of that of a singular isothermal sphere. We conclude that several of these sources may be undergoing an intense accretion phase and find in all the cases that the accretion luminosity exceeds the stellar luminosity. We discuss the implications of this phase on the formation of massive stars.

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The Nature of the Radio Continuum Sources Embedded in the HH 7-11 Region and its Surroundings

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Using the Very Large Array, we have carried out sensitive radio continuum observations at 6 and 3.6 cm of the HH 7-11 region, detecting a total of 44 radio sources in the $8' \times 8'$ region centered at this HH complex. The majority of these sources, at least 26 of them, are believed to be associated with young objects in the cloud. Among these sources are found candidates to power all the CO outflows observed in the region. For the first time, we detect at centimeter wavelengths counterparts to the young objects IRAS2A, IRAS2B, ASR51, ASR7, MMS 2, and IRAS4C, and to the foreground G2IV star BD+30°547. There is a strong correlation between the far-infrared and millimeter sources reported previously and the centimeter sources discussed here. Most likely, this correlation results from the fact that young embedded stars systematically have ionized outflows. Under these assumptions, the far-infrared and millimeter emission will originate from dust heated in the surroundings of the star, while the centimeter emission will come from the ionized flow. However, in two of the sources detected, the centimeter emission appears to have a significant contribution from heated dust. Two of the detected sources are time-variable, circularly polarized sources, one of them associated with a previously known T Tauri star. The results of our study suggest that sensitive radio continuum studies of other active star-forming regions could reveal a similar diversity of centimeter wavelength sources.

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

The Stellar Composition of the Star Formation Region CMa R1: I. Results from new photometric and spectroscopic classifications

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A new photometric and spectroscopic survey of the star formation region (SFR) CMa R1 is described. In a sample

of 165 stars brighter than 13th mag., 88 stars were found to be probable members of the SFR. They are defined as early-type stars with $E(B - V) \geq 0^m16$, which corresponds to a distance of about 1 kpc. Seventy four of the probable members are B stars. Nineteen stars are possibly associated with an *IRAS* point source. We derive a most probable distance of 1050 ± 150 pc to the association. It appears that about 80 candidate members are pre-main sequence stars with ages younger than 6 million year, while the main sequence extends over 6.0–7.6 magnitudes, which is consistent with star formation starting about 8 million years ago and continuing until at least half a million years ago. Two bright B stars in the association (GU CMa and FZ CMa) seem to be much older and probably do not originate from the same star-formation episode. The star formation efficiency appears to increase roughly monotonically with time up to half a million years ago. From our data, we conclude that only a minor fraction of the stars has been created through the scenario suggested by Herbst & Assoua (1977), in which the members of CMa R1 form by compression of ambient material by a supernova shock wave. An extensive search for candidate members with H α emission did not reveal new Herbig Ae/Be candidates, so that the number of stars in this class seems to be limited to four: Z CMa, LkH α 218, LkH α 220 and possibly HD 53367.

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Preprints: <http://www.astro.uva.nl/~mario/publist.html>

Movies: http://www.astro.uva.nl/~mario/cluster_movies.html

Radio counterparts to extreme X-ray YSO's

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We search for radio counterparts to two recently-detected strong X-ray sources associated with highly embedded young stellar objects (SVS4/EC 95 and SVS16). We detect a radio source (S68-2) consistent with the position of EC95. We fail to detect a counterpart for SVS16, and place upper limits on its quiescent radio brightness. For S68-2, we show that the radio source has a falling spectrum, suggestive of a gyrosynchrotron emission mechanism, and that it is variable on a timescale of years. We search for, but do not detect, evidence for flaring activity on timescales of minutes to hours. We also search for, but do not detect, circular polarisation. We derive the radio luminosity and compare the object to an empirical X-ray – radio luminosity relationship established for dMe stars. We find that the object is consistent with the dwarfs relation, but is unusually X-ray rich compared to other high-luminosity coronal sources. By comparing the objects to a sample of active galactic nuclei in the L_X – L_R diagram, we rule out the possibility that either object is a background AGN. We discuss the ways in which a normal stellar coronal model might be modified to explain the strong, X-ray rich characteristics of the source, which appears to be the most extreme stellar corona yet found.

Accepted by Astronomy & Astrophysics

Preprint available from:

http://www.astro.phys.ethz.ch/papers/smith/smith_p_m.html

A Cluster of Young Stellar Objects in L1211

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We present millimeter continuum and line observations of a dense core in L1211, a member of the Cepheus cloud complex. We find a small cluster of at least 4 millimeter (mm) sources with no optical counterpart, but each associated with near infrared (NIR) diffuse emission. The strongest mm source has no NIR point-like counterpart, and constitutes a good candidate for a Class 0 object. The other mm objects seem associated with NIR sources and most likely belong

to Class I, as also suggested by the spectral energy distributions derived from combining our mm data with IRAS HIREs fluxes. As evidenced by our line data, the mm sources are embedded in an elongated, turbulent core of about $150 M_{\odot}$ of mass and 0.6 pc length. Two of the millimeter sources power bipolar molecular outflows, another signature of their extreme youth. The outflows are well resolved by our observations and seem to have unrelated orientations.

The combination of millimeter sources and bipolar outflow emission indicates that multiple star formation in L1211 has occurred during a short period of time (a few 10^5 yr). The lack of a noticeable enhancement in the number of NIR sources suggests that the core has not had enough time to form a cluster, so we infer that L1211 is undergoing a first episode of star formation.

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An Accretion-Ejection Instability in magnetized disks

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We present an instability occurring in the inner part of disks threaded by a moderately strong vertical (poloidal) magnetic field. Its mechanism is such that a spiral density wave in the disk, driven by magnetic stresses (rather than self-gravity as in galactic spirals), becomes unstable by exchanging angular momentum with a Rossby vortex it generates at its corotation radius. This angular momentum can then “leak” as Alfvén waves emitted toward the corona of the disk thus providing, as an element of the accretion process, an energetic source for a wind or a jet. As galactic spirals, this instability forms low azimuthal wavenumber, standing spiral patterns which might provide an explanation for low-frequency QPOs in low-mass X-ray binaries.

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Atomic Carbon Is a Temperature Probe in Dark Clouds

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We have mapped the C I $^3P_1 \rightarrow ^3P_0$ line at 492 GHz in three molecular clouds immersed in weak ultraviolet radiation fields, TMC-1, L134N, and IC 5146. In all three clouds, the C I peak $T_A^* \sim 1$ K, with very small dispersion. The spatial C I distribution is extended and rather smooth. The $J = 2 \rightarrow 1$ transitions of CO isotopomers were observed at the same angular resolution as C I. The C I peak T_A^* is typically a third of the peak T_A^* of $^{13}\text{CO } J = 2 \rightarrow 1$, and the C I emission is usually more extended than emission in ^{13}CO or $\text{C}^{18}\text{O } J = 2 \rightarrow 1$. The C I linewidth is close to the $^{13}\text{CO } J = 2 \rightarrow 1$ linewidth, larger than the $\text{C}^{18}\text{O } J = 2 \rightarrow 1$ line width, and smaller than the $^{12}\text{CO } J = 2 \rightarrow 1$ linewidth. The shapes of these lines occasionally differ significantly, probably because of the combined effects of differing opacities and the physical separation of the line forming regions. The uniformity of the C I peak T_A^* is remarkable for a line in the Wien portion of the Planck function and indicates a very uniform excitation temperature. This uniformity is best explained if the line is opaque and thermalized. If so, the C I line probes kinetic temperature in clouds exposed to low ultraviolet fluxes. This conclusion has significant implications for the thermal balance in such clouds. At $A_V \simeq 2$, these clouds have a remarkably constant temperature from place to place and from cloud to cloud (7.9 ± 0.8 K). Photodissociation region models of clouds immersed in the mean interstellar radiation field tend to predict stronger lines than we see, but this may be an artifact of assumptions about the temperature.

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<http://www.nro.nao.ac.jp/~kt/ktpreprint.html>

ISO spectroscopy of shocked gas in the vicinity of T Tau

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We present the results of ISO SWS and LWS spectroscopy of the young binary system T Tau. The spectrum shows absorption features due to H₂O ice, CO₂ ice, gas-phase CO and amorphous silicate dust, which we attribute to the envelope of T Tau S. We derive an extinction of $A_V = 17^{m}4 \pm 0^{m}6$ towards this source. Detected emission lines from H I arise in the same region which is also responsible for the optical H I lines of T Tau N. These lines most likely arise in a partially ionized wind. Emission from the infrared fine-structure transitions of [S I], [Ar II], [Ne II], [Fe II], [Si II], [O I] and [C II] was also detected, which we explain as arising in a ≈ 100 km s⁻¹ dissociative shock in a fairly dense (5×10^4 cm⁻³) medium. Pure rotational and ro-vibrational emission from molecular hydrogen was detected as well. We show the H₂ emission lines to be due to two thermal components, of 440 and 1500 K respectively, which we attribute to emission from the dissociative shock also responsible for the atomic fine-structure lines and a much slower (≈ 35 km s⁻¹) non-dissociative shock. The 1500 K component shows clear evidence for fluorescent UV excitation. Additionally, we found indications for the presence of a deeply embedded ($A_V > 40^m$) source of warm H₂ emission. We suggest that this component might be due to a shock, caused by either the outflow from T Tau S or by the infall of matter on the circumstellar disk of T Tau S.

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<http://www.astro.uva.nl/~mario/publist.html>

Chemical evolution ahead of Herbig–Haro objects

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Compact regions of enhanced HCO⁺ and NH₃ emission have been detected close to a number of HH objects. An interpretation of these detections is the following: a transient clump within the molecular cloud has been irradiated by the shock that generates the HH object. The irradiation releases icy mantles from the grains within the transient clump and initiates a photochemistry. On the basis of this picture, we have developed an extensive chemical model which predicts that a wide range of species, other than NH₃ and HCO⁺, should also be detectable. These include CH₃OH, H₂S, C₃H₄, H₂CO, SO, SO₂, H₂CS, and NS. The chemical effects should last $\sim 10^4$ years.

Accepted by MNRAS

Multidimensional self-consistent radiative transfer simulations based on the Monte-Carlo method

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We developed the first Monte-Carlo code for three-dimensional self-consistent continuum radiative transfer calculations. The density structure of the dust configuration (disk/envelope/molecular cloud core) can be chosen arbitrarily as well as the number, configuration, and radiation parameters of the stars inside this configuration. Binaries and multiple stellar systems (with or without disks around the stars) surrounded by a dusty environment represent typical applications

for this code. Apart from the dust temperature, intensity and emergent spectral energy distribution, the polarization of light can be calculated. These polarization maps provide additional information about the geometrical structure and chemical composition of dusty media.

As the first application of our code, we simulated the radiative transfer in a protostellar disk around a star ($M = 1.14 M_{\text{Sun}}$) and a fragmented molecular cloud core. The dust density and temperature distributions have been taken from hydrodynamical simulations.

Accepted by Astron. & Astrophys.

<http://www.tls-tautenburg.de/research/tls-research/pub99.html>

The Formation of Protostellar Disks III. The Influence of Gravitationally Induced Angular Momentum Transport on Disk Structure and Appearance

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Hydrodynamical two-dimensional calculations are presented for the evolution of collapsing, rotating protostars, including the effects of radiative acceleration and angular momentum transport. The initial cloud is assumed to be a uniformly rotating centrally condensed sphere with $\rho \propto r^{-2}$. Results are presented for masses of $1 M_{\odot}$, $2 M_{\odot}$, and $10 M_{\odot}$, over times comparable to protostellar lifetimes. The calculations show how a warm, quasi-hydrostatic disk surrounding a central unresolved core forms, grows in mass and size, and accretes onto the central object. As a result of the accretion of material from the parent cloud, the disk is encased in one or two accretion shock fronts, located several scale heights above the equatorial plane. During accretion the disks grow radially due to the effects of angular momentum transport, which according to our model arises from tidally induced gravitational torques. In this manner quasi-static disks in excess of several 1000 AU in radius can be produced. Accretion onto the central object slows down, however, and rather long time scales $M/\dot{M} > 10^7$ yr are reached while an appreciable fraction of the total mass ($\approx 35\%$) is still in the disk. In order to further reduce the disk mass on a shorter time scale processes not considered here must be invoked. Alternatively, if the initially selected angular momentum is significantly lower, smaller disk sizes would result. Frequency-dependent radiative transfer calculations at selected ages — including the effects of scattered radiation in the infrared and optical spectral regimes — show how the continuum spectra of the structure depend on the disk’s orientation and age and how the observed isophotal contours vary with wavelength and viewing angle. Because of the strong dependence on viewing angle, continuum spectra alone should not be used to estimate the evolutionary stage of development of these objects. The infrared flux at $\sim 10\mu\text{m}$ can vary by orders of magnitude between pole-on and edge-on views, and the inferred total bolometric luminosity will vary by up to a factor ~ 30 as a function of viewing angle during much of the lifetime of accreting circumstellar disks. We conclude that near and mid-infrared searches for disks will be strongly biased towards pole-on orientations due to this “flashlight” effect.

Accepted by Astrophys. J.

Newly Discovered Herbig-Haro Objects in NGC 2068 and NGC 2071 Regions

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Taking the advantage of the large field of view at the 60/90cm Schmidt telescope of Beijing Astronomical Observatory (BAO), we were able to carry out a wide-field survey of Herbig-Haro (HH) objects in the nearby star forming regions including Perseus, Taurus, Orion and other regions. In a $58' \times 58'$ field centered at NGC 2068 and NGC 2071 (M78),

two active regions of star formation in the giant molecular cloud complex L1630, we found 17 HH objects exhibiting prominent [SII] emission but without continuum emission. Among these, we confirmed all the 11 known HH objects listed in Reipurth (1999) in this field. In addition, we discovered another six new HH objects, including HH 437, HH 438A-C, HH 440A & B, HH 442 - HH 443, and HH 452A & B. These objects demonstrate a variety of morphological structures: from knot to nebula. The discovery of these HH objects demonstrates strong activity of young stellar objects in the region we are studying. The large-scale spatial distribution of HH objects in the region is discussed by combination of our results and previous data.

Accepted by Astron. J. (Sept. issue)

New Jobs

Research Position at the Astrophysical Institute Jena

The Astrophysical Institute and University Observatory at Jena (Germany) invites applications for a postdoctoral position in the field of millimetre interferometry. The scientific goal of the project is the search for disks around intermediate-mass and high-mass stars. The project will be performed in close collaboration with Karl Menten from the Max Planck Institute for Radioastronomy in Bonn. It should make use of the Plateau de Bure interferometer. Appointment is for two years. Salary will be according to the German Public Service Scale (BAT-O IIa).

The applicant is expected to participate actively in the research group in Jena which is specialized in astrophysical processes related to the formation of stars and planets. He should have demonstrated skills in millimetre interferometry.

Applicants should send a letter of application, a brief description of research interest and past experience, a curriculum vitae including bibliography, and names of two persons ready to provide letters of recommendation upon request by August 31st to:

Prof. Dr. Thomas Henning
Astrophysical Institute and University Observatory
Friedrich Schiller University Jena
Schillerga'schen 3
D-07745 Jena, Germany

Women and handicapped are encouraged to apply.

Informal inquiries are welcome and should be directed to: Prof. Dr. Th. Henning, henning@astro.uni-jena.de, Tel. 03641-947530

Further information about the research in Jena under: <http://www.astro.uni-jena.de/>

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New Books

Interstellar Turbulence

Edited by **J. Franco** and **A. Carramiñana**

These are the proceedings of a conference held in Mexico in January 1998, where astronomers and physicists met to discuss and review our current understanding of interstellar turbulence. Much work has been done in recent years on interstellar turbulence both observationally, from the optical to the radio, as well as theoretically, thanks to improved computing techniques. The book presents an overview of recent progress and outstanding problems of a field that is of great importance for our understanding of star formation processes.

The book contains the following chapters:

- Turbulence in the Interstellar Medium: a Retrospective Review** *G. Münch*
Mechanism of Formation of Atmospheric Turbulence Relevant for Optical Astronomy *R. Avila & J. Vernin*
Properties of Atomic Gas in Spiral Galaxies *R. Braun*
Turbulence in the Ionized Gas in Spiral Galaxies *R. Walterbos*
Probing Interstellar Turbulence in the Warm Ionized Medium using Emission Lines *S. Tuftte et al.*
The Spectrum & Galactic Distribution of MicroTurbulence in Diffuse Ionized Gas *J. Cordes*
Small Scale Structure and Turbulence in the Interstellar Medium *S. Spangler*
What is the Reynolds Number of the Reynolds' Layer? *R. Benjamin*
Photoionized Gas in the Galactic Halo *C. McKee & J. Slavin*
Turbulent Heating of the Diffuse Ionized Gas *A. Minter & D. Balser*
Cosmic Rays in Interstellar Turbulence *R. Jokipii*
Turbulence in Line-Driven Stellar Winds *S. Owocki*
An Introduction to Compressible MHD Turbulence *A. Pouquet*
Turbulence in Atomic Hydrogen *A. Lazarian*
Supershells in Spiral Galaxies *D. Thilker*
The Size Distribution of Superbubbles in the Interstellar Medium *S. Oey & C. Clarke*
Large-Scale Motions in the ISM of Elliptical and Spiral Galaxies *J. Bregman et al.*
Vortical Motions Driven by Supernova Explosions *M. Korpi*
The Intermittent Dissipation of Turbulence: is it Observed in the Interstellar Medium? *E. Falgarone*
Chemistry in Turbulent Flows *R. Gredel*
Supersonic Turbulence in Giant Extragalactic HII Regions *J. Melnick et al.*
Turbulence in HII Regions: New Results *G. Joncas*
Hypersonic Turbulence of H₂O Masers *C. Gwinn*
Water Masers Tracing Alfvénic Turbulence and Magnetic Fields in W51 M and W49 N *T. Liljeström & K. Leppänen*
Turbulence in the Ursa Major Cirrus Cloud *M.-A. Miville-Deschênes et al.*
The Collisions of HVCs with a Magnetized Gaseous Disk *A. Santillán et al.*
The Initial Stellar Mass Function as a Statistical Sample of Turbulent Cloud Structure *B. Elmegreen*
The Structure of Molecular Clouds: are they Fractal? *J. Williams*
Diagnosing Properties of Turbulent Flows from Spectral Line Observations of the Molecular Interstellar Medium *M. Heyer*
Centroid Velocity Increments as a Probe of the Turbulent Velocity Field in Interstellar Molecular Clouds *D.C. Lis et al.*
High-Resolution C¹⁸O Mapping Observations of Heiles' Cloud 2 - Statistical Properties of the Line Width *K. Sunada & Y. Kitamura*
Observations of Magnetic Fields in Dense Interstellar Clouds: Implications for MHD Turbulence and Cloud Evolution *R. Crutcher*
The Density PDFs of Supersonic Random Flows *A. Nordlund & P. Padoan*
Turbulence as an Organizing Agent in the ISM *E. Vásquez-Semadeni & T. Passot*

Turbulence and Magnetic Reconnection in the Interstellar Medium *E. Zweibel*
The Evolution of Self-Gravitating, Magnetized, Turbulent Clouds: Numerical Experiments *E. Ostriker*
Super-Alfvénic Turbulent Fragmentation in Molecular Clouds *P. Padoan & A. Nordlund*
Decay Timescales of MHD Turbulence in Molecular Clouds *M.-M. Mac Low et al.*
Numerical Magnetohydrodynamic Studies of Turbulence and Star Formation *D.S. Balsara et al.*
Direct Numerical Simulations of Compressible Magnetohydrodynamical Turbulence *J. Stone*
Fragmentation in Molecular Clouds: The Formation of a Stellar Cluster *R. Klessen & A. Burkert*
Accretion Disk Turbulence *C. Gammie*

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