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Abstracts of recently accepted papers

On the Evolution of the Stellar Mass Spectrum: Possible Evidence for Stellar Evaporation

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The authors continue the analysis of the results of their preceding paper where a pure coagulation model was applied to star clusters in general. By combining in a certain way the free parameters of the model, it is possible to evaluate the ratio of the total mass of the cluster as it is today to what it was at its formation, according to the model. A correlation is found between this ratio and the age of the cluster. The analysis of this correlation also gives order of magnitude estimates of different processes such as accretion rate, evaporation rate, and timescale of disruption by evaporation (or mean life expectancy). These estimates are found to be in agreement with other published results. It is also found that the mass-loss rate of the cluster is proportional to the amount of coagulation that occured. All in all, it is shown that the coagulation model, although simplistic, merits more attention.

Accepted by Ap. J.

A submillimetre survey of W49A: support for the cloud-cloud collision model of W49N.

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Results are presented of a JCMT continuum mapping study of the massive star-forming region W49A at 450, 800 and 1100 μm. The three known far-infrared components of the source, W49N, W49SE and W49SW, are observed at all wavebands. The flux densities, temperatures, luminosities and gas masses of the three sources are derived. In addition, a new source is detected at 450 μm, 80 arcsec east of W49N, which is here labelled W49NE. It is seen that W49N is significantly more massive than the other sources, and is the only one to contain an extended, cold dust component. In the highest resolution dataset, taken at 450 μm, it can be seen that the peak of the source W49N is at least double, with a suggestion of a third component. This is consistent with recently published $C^{34}S$ data, which appear to show that the cluster of HII regions seen in W49N is the result of star formation triggered by a cloud-cloud collision. The agreement between our data and the $C^{34}S$ data, in terms of both morphology and relative masses, leads us to support this hypothesis.

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Fragmentation in a Centrally Condensed Protostar

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Hydrodynamical calculations in three space dimensions of the collapse of an isothermal, centrally condensed, rotating 1 $M_\odot$ protostellar cloud are presented. A numerical algorithm involving nested subgrids is used to resolve the region where fragmentation occurs in the central part of the protostar. A previous calculation by Boss, which produced a hierarchical multiple system, is evolved further, at comparable numerical resolution, and the end result is a binary, with more than half of the mass of the original cloud, plus a central object formed from the merger of small inner fragments. The orbital separation of the main binary increases with time as a result of accretion of high-angular momentum material and as a result of merging with fragments that have formed farther out. Repeating the calculation with significantly higher resolution, we find that a sequence of binaries can be induced by fragmentation of circumbinary disks. The stability of the resulting multiple system is investigated using n-body calculations, which indicate that such a system would transform on a short time scale into a more stable hierarchical structure. The outermost and most massive binary which forms in the high-resolution run has properties similar to that of the binary found in the low-resolution calculation. Thus the basic outcome is shown to be independent of the numerical spatial resolution. The high-resolution run, in addition, leads to the formation of an inner system of smaller fragments, which might be important for the understanding of the origin of close binaries with low-mass components and of low mass single stars.

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The Steady Structure of a Jet/Cloud Interaction. I. The Case of a Plane-Parallel Stratification

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The interaction between a jet and a stratified cloud (of characteristic size much larger than the jet radius) leads to a final configuration in which the jet has bored a hole through the cloud. This interaction results in a change of the direction, velocity, density and diameter of the jet beam. A simple model, based on Bernoulli's theorem can be integrated analytically for the case of a plane-parallel, exponential cloud pressure stratification. This model shows that a substantial deflection of the jet beam can be obtained for the adiabatic case (relevant for extragalactic jets), with the jet eventually emerging upwards from the stratified cloud with characteristics (e. g., velocity, density, temperature and diameter) which are basically identical to the ones of the incident jet beam. However, for the radiative case (relevant for Herbig-Haro jets) a smaller deflection is obtained, with the jet beam eventually becoming almost parallel to the isobars of the plane-parallel cloud stratification. We also find that while a low Mach number jet (with $M_0 \sim 1$) changes direction over a distance of a few environmental pressure scale heights, a high Mach number ($M_0 \sim 10$) jet is deflected only over distances of many pressure scale heights. Because of this, high Mach number jets will go through stratified clouds with depths of only a few pressure scale heights without an appreciable change of direction. The analytic solutions are finally compared with steady, "slab jet" adiabatic and radiative numerical simulations, showing a remarkably good agreement between the analytic and numerical results.

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A Possible Mechanism for Wiggling Protostellar Jets from 3D Simulations in a Stratified Ambient Medium

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Most collimated supersonic protostellar jets show a collimated wiggling, and knotty structure (e.g., the Haro 6-5B jet) and frequently reveal a long gap between this structure and the terminal bow shock. In a few cases, there is no evidence of such a terminal feature. We present three-dimensional smoothed particle hydrodynamical simulations which suggest that this morphology may be due to the interaction of the propagating cooling jet with a non-homogeneous ambient medium. In regions where the ambient gas has an increasing density (and pressure) gradient, we find that it tends to compress the cold, low-pressure cocoon of shocked material that surrounds the beam, destroy the bow shock-like structure at the head, and enhance beam focusing, wiggling, and internal traveling shocks. In ambient regions of decreasing density (and pressure), the flow widens and relaxes, becoming very faint. This could explain "invisible" segments in systems like the Haro 6-5B jet. The bow shock in these cases could be a relic of an earlier outflow episode, as previously suggested, or the place where the jet reappears after striking a denser portion of the ambient medium.

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Near-IR and optical observations of an obliquely viewed bow shock – AS 353A/HH 32

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High-resolution infrared maps and echelle spectroscopy of the emission from warm molecular hydrogen in the AS 353A/HH 32 outflow are presented. H_2 v=1-0 S(1) images are compared with high-quality optical [S II] $\lambda\lambda 6716, 6731$, H$\alpha$ and I-band images; we find that H_2 line emission "envelopes" the HH 32A bow shock, extending downwind beyond its western edge. The H_2 v=1-0 S(1) line profiles in HH 32 are all single peaked and gaussian or triangular in shape. The lines are rather narrow, typically 20 – 30 km s^{-1} (including instrumental smoothing) with peaks that are red-shifted by $\sim 8 - 25$ km s^{-1} relative to the source radial velocity. Although the H_2 data infer low velocities, we nevertheless find that the data are consistent with the high-velocity bow shock models ($V \sim 300 - 350$ km s^{-1}; $\theta \sim 15° - -30°$ to the line of sight) used to interpret earlier optical data.

We also report the discovery of three new Herbig-Haro objects. Designated HH 332, these features are evident only in our [S II] and Hα images, and not in our I-band image (they are not detected in H_2). They are therefore regarded as bona-fide HH objects associated with a previously unknown outflow.

A PostScript copy of this paper is available via the WWW from http://atlas.cp.dias.ie/∼cdavis/ or by post from one of the authors.

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Can Nonlinear Hydromagnetic Waves Support a Self-Gravitating Cloud?

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Using self-consistent magnetohydrodynamic (MHD) simulations, we explore the hypothesis that nonlinear MHD waves dominate the internal dynamics of galactic molecular clouds. Our models employ an isothermal equation of state and allow for self-gravity. We adopt "slab-symmetry," which permits motions $\mathbf{v}_\perp$ and fields $\mathbf{B}_\perp$ perpendicular to the mean field, but permits gradients only parallel to the mean field. This is the simplest possible geometry that relies on waves to inhibit gravitational collapse along the mean field. In our simulations, the Alfvén speed $v_{\rm A}$ exceeds the sound speed $c_{\rm s}$ by a factor $3-30$, which is realistic for molecular clouds. We simulate the free decay of a spectrum of Alfvén waves, with and without self-gravity. We also perform simulations with and without self-gravity that include small-scale stochastic forcing, meant to model the mechanical energy input from stellar outflows.

Our major results are as follows: (1) We confirm that the pressure associated with fluctuating transverse fields can inhibit the mean-field collapse of clouds that are unstable by Jeans's criterion. Cloud support requires the energy in Alfvén-like disturbances to remain comparable to the cloud's gravitational binding energy. (2) We characterize the turbulent energy spectrum and density structure in magnetically-dominated clouds. The perturbed magnetic and transverse kinetic energies are nearly in equipartition and far exceed the longitudinal kinetic energy. The turbulent spectrum evolves to a power-law shape, approximately $v_{\perp,\,k}^2 \approx B_{\perp,\,k}^2/4\pi\rho \propto k^{-s}$ with $s \sim 2$, i.e. approximately consistent with a "linewidth-size" relation $\sigma_v(R) \propto R^{1/2}$. The simulations show large density contrasts, with high density regions confined in part by the pressure of the fluctuating magnetic field. (3) We evaluate the input power required to offset dissipation through shocks, as a function of $c_{\rm s}/v_{\rm A}$, the velocity dispersion σ_v, and the characteristic scale λ of the forcing. In equilibrium, the volume dissipation rate is $5.5(c_{\rm s}/v_{\rm A})^{1/2}(\lambda/L)^{-1/2} \times \rho\sigma_v^3/L$, for a cloud of linear size L and density ρ. (4) Somewhat speculatively, we apply our results to a "typical" molecular cloud. The mechanical power input required for equilibrium (tens of $L_\odot$), and the implied star formation efficiency ($\sim 1\%$), are in rough agreement with observations. Because this study is limited to slab symmetry and excludes ion-neutral friction, the dissipation rate we calculate probably provides a lower limit on the true value.

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Preprint available at http://cfa-www.harvard.edu/ gammie/MHD.ps

The nature of the radio sources within the Cepheus A star-forming region

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We present multifrequency, matching beam, VLA radio continuum observations of the Cep A East radio source, known to consist of 16 compact ($\sim 1''$) components clustered within a 25" radius region, most of which are aligned in stringlike structures. We find that the spectral indices of the emission from these compact objects, in the frequency interval from 1.5 to 15 GHz, cover a wide range, from –0.6 to 0.7. Positive spectral indices are exhibited by sources 2, 3b, 3c and 3d. The first and last of these objects, the brightest sources within Cep A East, exhibit in addition elongated morphologies and angular-size and flux-density dependences with frequency which suggest they correspond to confined jets of ionized gas.

Most of the objects appearing in string structures exhibit a mixture of flat and negative spectral indices across their faces, which indicates the presence of both thermal and non-thermal emission. The spectral indices of the integrated emission from sources 1b, 4, 6 and 7a are in the range between -0.3 and -0.1, while those of sources 1a, 5, 7b, and 7c are even more negative ($-0.6 \leq \alpha \leq -0.4$). We suggest that the radio emission from the string sources arises in shocks resulting from the interaction of confined stellar winds with the surrounding medium. The duality in emission mechanisms is expected in shock waves where a small fraction of the electrons are accelerated to relativistic velocities,

giving rise to nonthermal emission, while most of the electrons produce thermal free-free emission. We find that the nonthermal emission dominates the thermal emission when the density of the thermal electrons is below a critical density of $\sim 5 \times 10^3$ cm^{-3}.

We also observed the Cep A West radio source, which consists of two compact components and an elongated, diffuse, champagne-like, structure. We find that the spectral index between 1.5 and 5 GHz of the peak and of the integrated emission from the latter component are -0.1 and -0.4, respectively. We suggest that the radio emission from the diffuse source arises from shocked gas at the edge of a cavity driven by a wind that originates from the brightest compact radio object within this region, which shows an spectral index at the peak of the emission of 0.6.

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Emission Line Images and Spectra of Asymmetric Bowshocks

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The shape and emission properties of asymmetric radiative bowshocks are investigated using analytic models. Two origins for the asymmetry are considered: (1) a transverse density gradient in the ambient medium into which the bowshock is propagating; (2) a skewness in the pressure distribution of the shocked jet gas that is driving the bowshock. In each case, images and position-velocity diagrams are presented for both high- and low-excitation emission lines. These models are applied to observations of bowshocks at the heads of jets from young stars. It is found that, in the case of Herbig-Haro 1, an ambient density gradient is the most likely cause of the asymmetry observed in this object.

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Available at: `http://caifan.astroscu.unam.mx/ will/papers/papers.html`

A two-wind interaction model for proplyds

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Recent *HST* observations of the Orion Nebula show the presence of compact ($\sim 2''$) emission-line objects ("proplyds") with bow-like morphologies and tails pointing away from the θ^1 Ori C star. We model these objects as the result of the interaction between the fast wind from θ^1 Ori C and slow dense winds from accretion disks around young, low mass stars, which are photoevaporated by the ionizing radiation coming from this massive star.

We develop a fully analytic model for this two-wind interaction, which shows that depending on the value of the dimensionless parameter $\lambda = F_0 c_0 / n_w {v_w}^2$, where c_0 is the sound speed of the ionized gas, F_0 is the ionizing photon flux impinging on the surface of the accretion disks, and $n_w {v_w}^2$ is the specific momentum flux of the wind from θ^1 Ori C, both "choked" subsonic (low λ) solutions and "free" supersonic (high λ) solutions can be found. We argue that for the case of θ^1 Ori C, this second, supersonic regime is relevant.

For the supersonic regime, we find that both the properties of the exciting star (θ^1 Ori C) and the size of the accretion disk that ejects the photoevaporated wind enter the solution only as a direct scaling of the size of the proplyd. The only physical parameter with a more complex effect on the problem is the orientation between the axis of the accretion disk and the direction to θ^1 Ori C.

We finally use this analytic model to produce predicted emission measure maps (which are directly compared to the *HST* images of O'Dell & Weng 1994). A good qualitative agreement is found at least for some of the proplyds observed in the Orion Nebula.

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Dust opacities for protoplanetary accretion disks — Influence of dust aggregates

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In this paper, we study the influence of grain aggregation in the early phases of protoplanetary accretion disks on the dust opacities. We include olivine ($[Fe,Mg]_2SiO_4$), orthopyroxene ($[Fe,Mg]SiO_3$), volatile and refractory organics, water ice, troilite (FeS), and metallic iron as major grain species and compare the results to the model with compact grains proposed by Pollack et al. (1994). We present both the wavelength-dependent mass absorption coefficients and the Rosseland mean opacities for different aggregation models. A major result is that the iron distribution in the different dust species plays a crucial role for the optical properties of the protoplanetary dust population. The Rosseland mean opacities for the recommended dust model with chemically inhomogeneous aggregates are summarized in a convenient analytical form.

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Studies of dense molecular cores in regions of massive star formation. IV. Multitransition CS-study towards southern H_2O masers in the longitude range l=308°-360°

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We have observed CS and $C^{34}S$ emission towards 33 H_2O maser positions in the southern sky ($\delta < -28°$) using the SEST telescope. Most of the sources were selected also for their association with strong IRAS sources. CS(2–1) was detected in all sources, with the possible exception of two. Most sources were also mapped in the transitions CS(5–4) and $C^{34}S$(2–1) and half of the sample in CS(2–1). CS and $C^{34}S$ transitions J=2–1, J=3–2 J=5–4 were measured towards the centres of the clouds as determined from the mapping. CS and $C^{34}S$ transitions J=7–6 were measured in about a half dozen clouds. CO(1–0) was measured in most clouds in order to determine the kinetic temperatures.

The CS column densities were calculated using the LTE approximation. All measurements were also analyzed using a spherical LVG model. We present the observational data and the results of this analysis.

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Non-LTE Excitation of H_2 in Magnetised Molecular Shocks

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The observed H_2 line ratios in OMC-1 and IC443 are not satisfactorily explained by conventional shock excitation models. We consider the microscopic collisional processes implicit in ambipolar diffusion models of magnetised C-shocks and show that non-LTE level populations and emission line ratios are an inevitable consequence of such models. This has important implications for the use of molecular hydrogen lines as diagnostics of shock models in molecular clouds

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The Nobeyama Millimeter Array Survey of Young Stellar Objects Associated with The Taurus Molecular Cloud

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We have carried out an interferometric survey of 3 mm continuum and CS ($J = 2 - 1$) line emissions toward thirteen optically invisible protostar candidates and six young T Tauri stars associated with the Taurus molecular cloud. The survey was made using Nobeyama Millimeter Array with the spatial resolutions of $2.''8$ – $10''$. The continuum emission was detected toward two protostar candidates and five T Tauri stars with being well coincident with optical or infrared objects. It was not spatially resolved and most probably originated from compact circumstellar disks. The CS emission was detected around eleven protostar candidates and two T Tauri stars. The detected CS condensations are extended with typical size and mass of ∼2,000 AU and 0.01 $M_\odot$, respectively.

Among the eleven protostar candidates with detectable CS emission, seven sources, i.e., IRAS 04016+2610 (L1489), IRAS 04169+2702, IRAS 04191+1503, IRAS 04239+2436, L1551-IRS5, IRAS 04325+2402, and IRAS 04365+2535, have the CS emission well coincident with infrared sources, while the other four show the CS emission separated away from known infrared sources. Most of the CS emission for the former sources may arise from the innermost part of their protostellar envelopes, while that for the latter sources may originate from compact, dense gas in the vicinity of the infrared sources. The CS gas toward L1489 and IRAS 04365+2535 have disk-like structures of ∼1,500 AU and ∼500 AU in radius, respectively, with the velocity gradient along their major axes. The velocity gradient of the disk-like structure around L1489 may be due to rotation, while the origin of velocity gradient around IRAS 04365+2535 is not clear. L1551-IRS5 shows compact CS emission, possibly arising from a disk, together with weak extended features which may be attributed to denser part of the outflow. The distribution of CS emission around IRAS 04368+2557 (L1527) is anticorrelated with its molecular outflow, suggesting that the CS gas may be a dense shell swept up by the outflow.

The 3 mm continuum detectability toward the protostar candidates is significantly smaller than what we would expect from statistics of T Tauri disks, which, we consider, may be an evolutionary effect that during the transitional phase from embedded protostars to revealed T Tauri stars either the disk mass has rapidly increased, or dust particles in the disks have significantly grown up, or both. For the embedded protostar candidates, the CS intensity is correlated with bolometric luminosity. This may mean that final stellar mass is correlated with the mass of dense cores.

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The Steady Structure of a Jet/Cloud Interaction. II. The Case of a Spherically Symmetric Stratification

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In a previous paper we have explored the final, steady configuration attained by a jet interacting with a dense cloud with a plane-parallel pressure stratification. We now extend this study to the interaction of a jet with a spherically symmetric pressure stratification, concentrating particularly on the case of a singular, isothermal sphere (with $P \propto r^{-2}$). With a simple model based on Bernoulli's theorem, we find that unless a high Mach number ($M_0 \sim 10$) jet hits the dense cloud head on (in other words with an impact parameter much smaller than the radius of the cloud), the final configuration attained by the jet/cloud interaction corresponds to the jet boring an almost straight path through the cloud. This result is true for the case of an adiabatic jet, and even more so for the radiative case. On the other hand, a low Mach number ($M_0 \sim 1$) jet will be substantially deflected in such a collision.

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Towards an Astrophysical Theory of Chondrites

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The chondrules, calcium-aluminum-rich inclusions (CAIs), and rims in chondritic meteorites could be formed when solid bodies are lifted by the aerodynamic drag of a magnetocentrifugally driven wind out of the relative cool of a shaded disk close to the star into the heat of direct sunlight. For reasonable self-consistent parameters of the bipolar

outflow, the base and peak temperatures reached by solid bodies resemble those needed to melt CAIs and chondrules. The process also yields a natural sorting mechanism that explains the size distribution of CAIs and chondrules, as well as their fine-grained and coarse-grained rims. After reentry at great distances from the original launch radius, the CAIs, chondrules, and their rims are compacted with the ambient nebular dust comprising the matrices to form the observed chondritic bodies.

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FUV irradiated molecular clumps: spherical geometry and density gradients

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We examine the effects of spherical geometry and density gradients on the thermal and chemical structure of photon dominated regions in individual molecular clumps inside molecular clouds. We investigate the effects of spherical geometry and density gradients on the [CII] fine-structure and ^{12}CO and ^{13}CO low-J rotational line intensities produced in clouds illuminated by external far-ultraviolet radiation fields. We compare plane-parallel and spherical models for a range of cloud parameters. The models are characterized by an UV intensity of $\chi = 1000$, a mean hydrogen particle density of n(H)= 10^5cm^{-3} and clump sizes ranging from R = 0.05 pc to R = 0.005 pc.

We argue that spherical models including density gradients are necessary to realistically account for the range of absolute and relative CII and CO line strengths observed in star forming cloud cores. We compare our model results in detail with observations of the Orion molecular cloud complex.

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The embedded stellar population in northern NGC 6334

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JHK imaging photometry is reported of an area of approximately $2' \times 3'$ centred on the far infrared source NGC 6334 I with limiting magnitudes $J = 18.3$, $H = 17.8$ and $K = 16.2$. More than 224 sources were detected in K-band, increasing by a factor of more than seven the number of objects found in previous near–IR surveys. Most of the sources are located in an area of about 3500 square arcsec centered around the massive young stellar object Irs1, which ionizes the compact HII region NGC 6334 F. The location of these sources and the analysis of the colour–colour and colour–magnitude diagrams suggest the presence of an embedded and young stellar cluster of size $\sim$ 70" (0.6 pc), and stellar density of about 1200 pc^{-3}. The star formation efficiency is estimated to be $SFE \simeq 0.25$. Only a few of the most luminous stars of the cluster were found to show large near-IR excesses but this may be due to the non-detection, at the shortest wavelength, of the majority of the highly reddened cluster members. The extinction of the region is very variable with a maximum of $A_V > 70$ in Irs2 while the average is $< A_V > \simeq 40$. Very close to the position of an H_2O maser associated with NGC 6334 I(N), a contracting core at an earlier evolutionary stage, we found six very red sources, one of which is a small and diffuse nebula seen only at 2.2 microns. Finally, the older and developed HII region NGC 6334 E was found to be probably ionized by a small cluster of at least 12 B0–B0.5 ZAMS stars

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Dissertation Abstracts

Class II Methanol Masers in Star Formation Regions

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Ph.D degree awarded: January 1996

In 1991 maser emission from the 5_1-6_0 A^+ transition of CH_3OH at a frequency of 6.7 GHz was discovered by Menten (1991). This transition is more common and stronger than the 12.2-GHz (2_0-3_{-1} E) transition discovered four years previously. This thesis contains the results of a detailed study of 6.7-GHz CH_3OH maser emission over a wide range of angular resolutions.

The University of Tasmania 26-m radio telescope has been used to perform a sensitive search for 6.7-GHz CH_3OH masers in a 28.5 square-degree region of the Galactic Plane. The search is complete, within a well defined velocity and flux density range. One hundred and eight 6.7-GHz CH_3OH masers were detected during the course of the survey, 57 of these being new detections. These new 6.7-GHz CH_3OH masers are generally weaker than those already known, but otherwise their spectral appearance is similar to those detected towards OH and 12.2-GHz CH_3OH masers. The sample of 6.7-GHz CH_3OH masers has been used to critically evaluate several *IRAS*-based search techniques and we find that all these techniques fail to detect a large fraction of the masers. Two targeted searches of the Large and Small Magellanic Clouds have been performed, resulting in the detection of three 6.7-GHz CH_3OH masers.

In addition, a search for 6.7-GHz CH_3OH megamasers was carried out toward 10 Extragalactic sources, nearly all of which are known OH or H_2O megamasers. No CH_3OH megamasers were detected with a peak flux comparable to the OH or H_2O megamasers in the galaxies searched.

Single dish spectra of 6.7- and 12.2-GHz CH_3OH masers are often complicated, with many spectral features spread over a velocity range of 10 km s^{-1} or more. High resolution observations of these maser sources show that each of the spectral features arise from a different region in the gas cloud. For OH and H_2O masers the high resolution spatial morphology typically shows little or no simple structure. Conversely, high resolution observations of 6.7- and 12.2-GHz CH_3OH masers (Norris et al. 1988; 1993) show that many have a simple curved, or linear morphology. The Australia Telescope Compact Array has been used to observe the radio continuum emission associated with three strong 6.7-GHz CH_3OH masers. It is shown that the position of the CH_3OH masers with respect to the continuum emission is consistent with the masers originating in a circumstellar disc.

Very Long Baseline Interferometry (VLBI) has been used to image strong class II CH_3OH maser emission associated with two star formation regions. The milli-arcsecond resolution images detected many new maser spots, but all of these follow the general morphology revealed by lower resolution observations. Comparison of the 6.7- and 12.2-GHz images for the CH_3OH masers associated with NGC 6334F shows that five of the spots are coincident to within the positional errors of the observations ($\approx$ 4 milli-arcseconds).

VLBI observations were also used to measure the size of the 6.7- and 12.2-GHz CH_3OH maser spots. These show that the maser spots contain structure on two different scales, one of the order of tens of astronomical units, the other between a few and ten astronomical units. These findings are supported by the imaging data and the VLBI observations of Menten et al. (1988 ; 1992). The sizes of the 6.7- and 12.2-GHz spots toward the same sources are similar, which suggests that they are not broadened by interstellar scattering.

This thesis is available on WWW at:
http://reber.phys.utas.edu.au/∼sellings/thesis.html

Stellar Populations of Deeply Embedded Young Clusters: Near–Infrared Spectroscopy and Emergent Mass Distributions

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The goal of this thesis is to test the following hypothesis: the initial distribution of stellar masses from a single "episode" of star formation is independent of the local physical conditions of the region. In other words, is the initial mass function (IMF) strictly universal over spatial scales $d < 1\ pc$ and over time intervals $\Delta\tau << 3 \times 10^6\ yrs$? We discuss the utility of embedded clusters in addressing this question. Using a combination of spectroscopic and photometric techniques, we seek to characterize emergent mass distributions of embedded clusters in order to compare them both with each other and with the field star IMF. Medium resolution ($R = 1000$) near–infrared spectra obtainable with the current generation of NIR grating spectrographs can provide estimates of the photospheric temperatures of optically–invisible stars. Deriving these spectral types requires a three–step process; i) setting up a classification scheme based on near–infrared spectra of spectral standards; ii) understanding the effects of accretion on this classification scheme by studying optically–visible young stellar objects; and iii) applying this classification technique to the deeply embedded clusters. Combining near–infrared photometry with spectral types, accurate stellar luminosities can be derived for heavily reddened young stars thus enabling their placement in the H–R diagram. From their position in the H–R diagram, masses and ages of stars can be estimated from comparison with theoretical pre–main sequence evolutionary models. Because it is not practical to obtain complete spectroscopic samples of embedded cluster members, a technique is developed based solely on near–IR photometry for estimating stellar luminosities from flux–limited surveys. We then describe how spectroscopic surveys of deeply embedded clusters are necessary in order to adopt appropriate mass–luminosity relationships. Stellar luminosity functions constructed from complete extinction–limited samples can then be used to characterize emergent mass distributions of deeply embedded young clusters. Because of systematic uncertainties in these models at the low–mass end, we adopt the ratio of intermediate ($10M_\odot > M_* > 1.0M_\odot$) to low–mass ($1.0M_\odot > M_* > 0.1M_\odot$) stars in order to compare these mass distributions to the Miller–Scalo IMF. As an example of this analysis we present a study of the embedded cluster associated with the NGC2024 nebula. Although this cluster contains an enhanced number of intermediate mass stars, we cannot distinguish the distribution of stellar masses from the field star IMF. A detailed comparison between the stellar luminosity functions of the embedded clusters associated with the NGC2024 cluster and the embedded population found in the Ophiuchus cloud cores suggests that it is unlikely they were drawn from the same parent population. After finding the evolutionary states and accretion properties of both clusters to be similar, we interpret the difference in stellar luminosity functions as a difference in their emergent mass distributions. Synthesizing results for NGC2024 and Ophiuchus with those from other studies of embedded clusters, we arrive at the following conclusions: i) the emergent mass distributions of most of the embedded young clusters considered are consistent with having been drawn from the Miller–Scalo IMF; and ii) there is a hint that regions of high central stellar density contain a greater proportion of intermediate mass stars.

Three-Dimensional Parallel Lattice Boltzmann Hydrodynamic Simulations of Turbulent Flows in Interstellar Dark Clouds

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Exploring the clumpy and filamentary structure of interstellar molecular clouds is one of the key problems of modern astrophysics. So far, we have little knowledge of the physical processes that cause the structure, but turbulence is suspected to be essential. In this thesis I study turbulent flows and how they contribute to the structure of interstellar dark clouds. To this end, three-dimensional numerical hydrodynamic simulations are needed since the detailed turbulent spatial and velocity structure cannot be analytically calculated. I employ the "Lattice Boltzmann Method", a recently developed numerical method which solves the Boltzmann equation in a discretized phase space. Mesoscopic particle packets move with fixed velocities on a Cartesian lattice and at each time step they exchange mass according to given rules. Because of its mainly local operations the method is well suited for application on parallel or clustered computers.

As part of my thesis I have developed a parallelized "Lattice Boltzmann Method" hydrodynamics code. I have improved the numerical stability for Reynolds numbers of up to $10^{4.5}$ and Mach numbers of up to 0.9 and I have extended the method to include a second miscible fluid phase. The code has been used on the three currently most powerful workstations at the "Max-Planck-Institut für Radioastronomie" in Bonn and on the massively parallel mainframe CM-5 at the "Gesellschaft für Mathematik und Datenverarbeitung" in St. Augustin. The simulations consist of collimated shear flows and the motion of molecular clumps through an ambient medium. The dependence of the emerging structure on Reynolds and Mach numbers is studied.

The main results are (1) that distinct clumps and filaments appear only at the transition between laminar and fully turbulent flow at Reynolds numbers between 500 and 5000 and (2) that *subsonic* viscous shear flows are capable of producing the dark cloud velocity structure. The unexpectedly low Reynolds numbers can be explained by the enlargement of the gas viscosity by magnetic fields of the order $10\mu G$ and the strong coupling between ionized and neutral gas. The occurrence of well-defined structure between the highly ordered laminar and the chaotic turbulent flow regimes can be interpreted in the framework of the "Edge of Chaos", i.e. the tendency of complex systems to show self-organization only at the transition between phases. In order to compare the simulations with observed data I have used the 100m radio telescope at Effelsberg to map the ground transition of sulphur monoxide toward the quiescent cold dark cloud L1512. The data show a clumpy structure that I interpret as a turbulent tail behind the dense central cloud.

This thesis is available on the World Wide Web. The PostScript file including 15 full color figures can be obtained at:

http://WWW.MPIfR-Bonn.MPG.de/iram/dmuders/dmuders.html

New Jobs

POST-DOCTORAL POSITION IN SACLAY, FRANCE

STAR FORMATION ASTRONOMY WITH ISO

The Saclay Astrophysics Department is seeking post-doctoral research associates who can help support its current research programs with the Infrared Space Observatory (ISO).

The Astrophysics Department ("Service d'Astrophysique") in Saclay is a major space astrophysics laboratory, and is also involved in instruments on the ground. In particular, the department has the main responsibility of the ISOCAM camera aboard the Infrared Space Observatory (ISO), and as such is involved in many ISO Core Program and Open Time observations. In addition, the Service d'Astrophysique, together with Institut d'Astrophysique Spatiale in Orsay, hosts a support center for the French Astronomical Community having access to ISO Open Time. The Saclay center is dedicated to ISOCAM and ISOPHOT support. A post-doctoral position is being offered in the field of star formation, which could begin as soon as June 1st, 1996. This position is for one year, with a possibility of extension. There is no restriction on nationality. The Saclay Center for Research is located about 15 km south-west of Paris, close to several other astronomy centers. A report on the current activities of the Department may be obtained upon request.

The Saclay Star Formation group is engaged in multi-wavelength studies of the stellar and gas/dust content of nearby molecular clouds, from the radio to the X-ray range. Various instruments are being used, such as the VLA, the IRAM 30m and interferometer, ESO telescopes and the ROSAT and ASCA satellites. The group's ISO projects include searches for protostars, studies of molecular cloud chemistry, and imaging of dust disks around young stars.

The successful applicant will be a young researcher (typically a recent Ph.D. recipient, with at most one previous post-doctoral position), with a very good record in the field of star formation and early stellar evolution. A strong interest in the observational program of ISO, together with a working knowledge of infrared and/or submillimeter wavelength observing methods and data reduction techniques (ground-based and/or space-borne), would be an advantage. This researcher will be an integral part of the Star Formation group, and is expected to play a significant role in its scientific activities, including data reduction and interpretation.

Send applications (including detailed scientific interests and research projects, vita, and publication list), and arrange to have three letters of recommendations sent, to:

Dr. Thierry Montmerle, Service d'Astrophysique, CEA/DAPNIA/SAp, Centre d'Etudes de Saclay,
91191 Gif-sur-Yvette Cedex, France.

E-mail: montmerle@cea.fr; Fax: (33) 1 69 08 92 66.

Deadline: Monday, March 4th, 1996.

Meetings

CALL FOR CONFERENCE PAPERS

Planetary Formation in the Binary Environment

The majority of stars in our Galaxy belong to multiple systems and these systems appear to be well established during the epoch of planet formation. The goal of this conference is to bring together the observationalists and theorists working in the areas star formation and planetary formation to discuss the implications of binary stars for planet formation.

The conference will be held at SUNY-Stony Brook, New York on June 16-18, 1996. It will include review papers and contributed poster papers. The conference is supported in part by the NASA Origins of Solar Systems Program.

Contributed papers are invited in the form of posters. Those wishing to attend should contact as soon as possible, but no later than April 15, 1996:

origins@sbast1.ess.sunysb.edu

or,

msimon@sbast1.ess.sunysb.edu and *ghez@urania.astro.ucla.edu*

Scientific Organizing Comm: P. Bodenheimer, A. Boss, R. Brown, C. Clarke, A. Ghez (Co-Chair), S. Lubow, J. Lissauer, P. Nicholson, C. Porco, M. Simon (Co-Chair), S. Strom, H. Zinnecker

Invited Speakers and Session Super-Chairs: R. Angel, P. Artymowicz, P. Bodenheimer, A. Boss, J. Bouvier, G. Bryden, A. Burkert, W. Brandner, A. Burrows, C. Clarke, A. Dutrey, P. Hartigan, E. Jensen, R. Kohler, S. Kulkarni, J. Lissauer, G. Marcy, R. Mathieu, M. McCaughrean, L. Mundy, L. Prato, D. Saumon, M. Shao, J. Stauffer, T. Takeuchi, R. White

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).

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

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