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From the Editor

Lately an increasing amount of Newsletters are returned with ″recipient unknown″ after the monthly mailing. Please do remember to send me an update of your new e-mail address when it changes, with over 750 recipients it is a very time consuming job to keep track of which addresses have permanent errors and which are just due to temporary problems. When the Newsletter has been returned three consecutive times from an address it is deleted from the mailing list.

I have been travelling extensively in recent months, and although I do my best to keep track of the abstracts received, it may occur that an abstract is lost. If this should happen to you, please accept my apology and send it once again.

Bo Reipurth

Abstracts of recently accepted papers

Externally Illuminated Young Stellar Environments in the Orion Nebula: Hubble Space Telescope Planetary Camera and UV Observations

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We present new 0.05″(22 AU) resolution narrow-band Hubble Space Telescope Planetary Camera images of externally illuminated young stellar objects embedded in the Orion Nebula. We also present 0.02″ (9 AU) resolution UV images of 7 externally illuminated proto-stellar environments and the first UV spectra that cover the spectral range between 1400 and 3000 Å. We discuss 43 objects for which the angular resolution has been improved over previous data by more than a factor of two. These young stellar objects are either embedded inside the Orion Nebula and externally illuminated by the Trapezium stars or located in front of the nebula and seen in silhouette. The visibility of young stars surrounded by diffuse matter is dominated by intense line emission from ionization fronts propagating into material photo–ablated from circumstellar disks by soft UV radiation. Near the Trapezium stars, the electron density at these ionization fronts is around 10^5 to 10^6 cm^{-3} and the radial intensity profiles of emission lines decrease roughly as r^{-3}, consistent with an approximately constant velocity diverging flow with an r^{-2} density profile. However, some radial intensity profiles are better fit with an exponential function. Low ionization fraction near the ionization front and the heating and acceleration of the photo–ablation flow by the conduction of heat from the shocked θ^1 Orionis C stellar wind bubble into the photo–ablation flow can explain deviations from the r^{-3} intensity profiles. Many young stars located within 30″ of θ^1 Orionis C are surrounded by concentric arcs of [OIII] and Hα emission located 0.5″ to 3″ from the ionization-front facing θ^1 Orionis C. These arcs may trace bow shocks formed by the interaction of the expanding photo–ablation flow with the fast stellar wind from θ^1 Orionis C. The [OIII] emission may be enhanced by UV radiation from θ^1 Orionis C, thermal conduction, and/or turbulent mixing of weakly-shocked photo-ablated gas with the thermalized shocked stellar wind. About 30% of the bright externally illuminated young stellar objects contain dark regions seen in silhouette against background nebular emission in Hα and the forbidden transitions of common ions that may trace circumstellar proto-planetary disks. In some sources, the region seen in silhouette in Hα and ionic transitions, are *bright* in the 6300 Å [OI] line. Most externally illuminated young stellar objects have dusty tails pointing radially away from the source of ionizing photons. Tails have an average length of 500 AU, independent of the projected distance from θ^1 Orionis C, are limb brightened in emission lines, and are sometimes seen in silhouette against background nebular light, indicating that they contain large column densities of gas and dust. We discuss a variety of tail formation mechanisms and conclude that initial conditions probably play a key role in their formation. The large fraction of young stellar objects with extended circumstellar structure, the mass limits on this structure, and the estimated mass loss rates are combined to produce an estimate for the photo–ionization age of the Orion Nebula. The derived photo-ionization age of the Orion Nebula is less than 10^5 years and possibly as short as 10^4 years.

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The Post-Shock Chemical Lifetimes of Outflow Tracers and a Possible New Mechanism to Produce Water Ice Mantles

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We have used a coupled time-dependent chemical and dynamical model to investigate the lifetime of the chemical legacy left in the wake of C-type shocks. We concentrate this study on the chemistry of H_2O and O_2, two molecules which are predicted to have abundances that are significantly affected in shock-heated gas. Two models are presented: (1) a three-stage model of pre-shock, shocked, and post-shock gas; and (2) a Monte-Carlo cloud simulation where we explore the effects of stochastic shock activity on molecular gas over a cloud lifetime. For both models we separately examine the pure gas-phase chemistry as well as the chemistry including the interactions of molecule s with grain surfaces. In agreement with previous studies, we find that shock velocities in excess of 10 km s^{-1} are required to convert all of the oxygen not locked in CO into H_2O before the gas has an opportunity to cool. For pure gas-phase models the lifetime of the high water abundances, or "H_2O legacy", in the post-shock gas is $\sim 4 - 7 \times 10^5$ years, independent of the gas density. A density dependence for the lifetime of H_2O is found in gas-grain models as the water molecules deplete onto grains at the depletion timescale.

Through the Monte Carlo cloud simulation we demonstrate that the time-average abundance of H_2O – the weighted average of the amount of time gas spends in pre-shock, shock, and post-shock stages – is a sensitive function of the frequency of shocks. Thus we predict that the abundance of H_2O, and to a lesser extent O_2, can be used to trace the history of shock activity in molecular gas. We use previous large-scale surveys of molecular outflows to constrain the frequency of 10 km s^{-1} shocks in regions with varying star-formation properties and discuss the observations required to test these results. We discuss the post-shock lifetimes for other possible outflow tracers (e.g. SiO, CH_3OH) and show that the differences between the lifetimes for various tracers can produce potentially observable chemical variations between younger and older outflows. For gas-grain models we find that the abundance of water-ice on grain surfaces can be quite large and is comparable to that observed in molecular clouds. This offers a possible alternative method to create water mantles without resorting to grain surface chemistry: gas heating and chemical modification due to a C-type shock and subsequent depletion of the gas-phase species onto grain mantles.

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Preprints available on the WWW at http://cfa-www.harvard.edu/∼ebergin/ or by request: ebergin@cfa.harvard.edu

A Search for Very low-mass Pre-Main Sequence stars in Taurus

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We present the initial results of a deep CCD survey for very low-mass pre-main sequence stars in selected fields of the Taurus molecular cloud complex. The results reported herein span a little over half a square degree in the dark clouds L1495, L1529, L1551 and B209. Our survey is complete down to $I_C \sim 19$, at $(R-I)_C \sim 2.5$, which enables us to probe well below the hydrogen burning limit at 1-2 Myr. From follow-up spectroscopic observations we have identified 9 new low-mass T Tauri stars (TTS). A large fraction of the new pre-main sequence objects (5/9) have very low masses as inferred from their late spectral types $\geq$ M5, and comparison with recent evolutionary tracks and Pleiades brown dwarfs suggests that our M6-M6.5 new TTS are very young brown dwarfs. Two of the new TTS may constitute a new, moderately embedded, binary Classical T Tauri system. The new young stars represent a $\sim 38\%$ increase in the pre-main sequence population known in our survey area and a factor ~ 2 increase in the number of late type TTS. In spite of our sensitivity we detect no young stars with spectral types later than $\sim$ M7. Our results illustrate the importance of spectroscopy in eliminating foreground M stars.

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(preprint available at http://cfa-www.harvard.edu/cfa/youngstars/)

CO, CI and CII observations of NGC 7023

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We present new data on the photodissociation regions associated with the reflection nebula NGC 7023, particularly the three bright rims to the north, south and east of the illuminating star HD 200775. ^{13}CO(3–2) emission, mapped at 20″ resolution at the Caltech Submillimeter Observatory (CSO), delineates a molecular cloud containing a cavity largely devoid of molecular gas around this star. Neutral carbon is closely associated with the ^{13}CO emission while ionized carbon is found inside and at the edges of the cavity. The ionized carbon appears to be, at least in part, associated with H Roman1. We have mapped the northern and southern rims in ^{12}CO(6–5) emission and found a good association with the H_2 rovibrational emission, though the warm CO gas permeates a larger fraction of the molecular cloud than the vibrationally excited H_2.

The column density contrast between the bright rims and the diffuse region inside and in front of the cavity is about 10. Despite the fact that the edges of the cavity are viewed edge-on, the carbon emission extends much further into the molecular gas than does the photodissociation region, as defined by the H_2 emission region. Geometrically, NGC 7023 consists of a sheet of dense molecular gas in which the star was born, subsequently blowing away much of the surrounding gas. The three bright rims are located at the edges of the remaining molecular cloud, and are viewed approximately edge-on.

The results are compared with PDR models, invoking direct illumination from the star, which are largely successful, except in explaining the presence of neutral carbon deep in the molecular cloud. We suggest that, in the particular case of NGC 7023, a second PDR has been created at the surface of the molecular cloud by the scattered radiation from HD 200775. This second PDR produces a layer of atomic carbon at the surface of the sheet, which increases the predicted [C]/[CO] abundance ratio to 10%, close to the observed value. Further tests for the applicability of PDR models in such regions are suggested.

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From Head to Sword, the Clustering Properties of Stars in Orion

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We investigate the structure in the spatial distributions of optically selected samples of young stars in the Head (λ Orionis) and in the Sword (Orion A) regions of the constellation of Orion with aid of stellar surface density maps and the two-point angular correlation function. The distributions of young stars in both regions are found to be non-random and highly clustered. Stellar surface density maps reveal three distinct clusters in the λ Orionis region. The two-point correlation function displays significant features at angular scales which correspond to the radii and separations of the three clusters identified in the surface density maps. Most ($\sim 80\%$) young stars in the λ Orionis region are presently found within these three clusters consistent with the idea that the majority of young stars in this region were formed in dense protostellar clusters which have significantly expanded since their formation.

Over a scale of ~ 0.05 to ~ 0.5 degrees the correlation function is well described by a single power-law which increases smoothly with decreasing angular scale. This suggests that within the clusters the stars are either themselves hierarchically clustered or have a volume density distribution which is falling steeply with radius. The relative lack of Hα emission-line stars in the one cluster in this region that contains OB stars suggests a timescale for emission-line activity of $< 4 \times 10^6$ years around late-type stars in the cluster and may indicate that the lifetimes of protoplanetary disks around young stellar objects may be reduced in clusters containing O stars.

The spatial distribution of young stars in the Orion A region is considerably more complex. The angular correlation function of the OB stars (which are mostly foreground to the Orion A molecular cloud) is very similar to that of the Hα stars located mostly within the molecular cloud. This suggests that both populations may have originated from a similar fragmentation process. Stellar surface density maps and modeling of the angular correlation function suggest that less than 1/2 of the OB and Hα stars in the Orion A cloud are presently within well defined stellar clusters. Although all the OB stars could have originated in rich clusters, a significant fraction of the Hα stars appear to have formed outside such clusters in a more spatially dispersed manner. This fact in conjunction with the close similarity of the angular correlation functions of the OB and Hα stars toward the molecular cloud, and the earlier indications of a relatively high star formation rate and high gas pressure in this cloud may indicate that older, foreground OB stars triggered the current episode of star formation in the Orion A cloud. One of the OB clusters (Upper Sword) which is foreground to the cloud does not appear associated with any of the clusterings of emission-line stars, again suggesting a timescale ($\lesssim 4 \times 10^6$ years) for emission-line activity and disk lifetimes around late-type stars born in OB clusters.

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Nonlinear Evolution of the Magnetorotational Instability in Ion-Neutral Disks

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We carry out three-dimensional magnetohydrodynamical simulations of the magnetorotational (Balbus-Hawley) instability in weakly-ionized plasmas. We adopt a formulation in which the ions and neutrals each are treated as separate fluids coupled only through a collisional drag term. Ionization and recombination processes are not considered. The linear stability of the ion-neutral system has been previously considered by Blaes & Balbus (1994). Here we extend their results into the nonlinear regime by computing the evolution of Keplerian angular momentum distribution in the local shearing box approximation. We find significant turbulence and angular momentum transport when the collisional frequency is on order 100 times the orbital frequency Ω. At higher collision rates, the two-fluid system studied here behaves much like the fully ionized systems studied previously. At lower collision rates the evolution of the instability is determined primarily by the properties of the ions, with the neutrals acting as a sink for the turbulence. Since in this regime saturation occurs when the magnetic field is superthermal with respect to the ion pressure, we find the amplitude of the magnetic energy and the corresponding angular momentum transport rate is proportional to the ion density. Our calculations show the ions and neutrals are essentially decoupled when the collision frequency is less than 0.01Ω; in this case the ion fluid behaves as in the single fluid simulations and the neutrals remain quiescent. We find that purely toroidal initial magnetic field configurations are unstable to the magnetorotational instability across the range of coupling frequencies.

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Envelope structure on 700 AU scales and the molecular outflows of low-mass young stellar objects

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Aperture synthesis observations of HCO^+ J=1–0, ^{13}CO 1–0, and C^{18}O 1–0 obtained with the Owens Valley Millimeter Array are used to probe the small scale ($5'' \approx 700$ AU) structure of the molecular envelopes of a well defined sample of nine embedded low-mass young stellar objects in Taurus. The interferometer results can be understood in terms of: (1) a core of radius $\lesssim$1000 AU surrounding the central star, possibly flattened and rotating; (2) condensations scattered throughout the envelope which may be left over from the inhomogeneous structure of the original cloud core or have grown during collapse; and (3) material within the outflow or along the walls of the outflow cavity. Masses of the central cores are 0.001–0.1 $M_\odot$, and agree well with dust continuum measurements. Averaged over the central $20''$ (3000 AU) region, an HCO^+ abundance of 4×10^{-8} is inferred, with a spread of a factor of 3 between the different sources. Reanalysis of previously presented single-dish data yields an HCO^+ abundance of $(5.0 \pm 1.7) \times 10^{-9}$, which may indicate an average increase by a factor of a few on the smaller scales sampled by the interferometer. Part of this apparent abundance variation could be explained by contributions from extended cloud emission to the single-dish C^{18}O lines, and uncertainties in the assumed excitation temperatures and opacities.

The properties of the molecular envelopes and outflows are further investigated through single-dish observations of ^{12}CO J=6–5, 4–3, and 3–2, ^{13}CO 6–5 and 3–2, and C^{18}O 3–2 and 2–1, obtained with the James Clerk Maxwell and IRAM 30 m telescopes along with the Caltech Submillimeter Observatory. Ratios of the mid-J CO lines are used to estimate the excitation temperature, with values of 25–80 K derived for the gas near line center. The outflow wings show a similar range, although $T_{\rm ex}$ is enhanced by a factor of 2–3 in at least two sources. In contrast with the well-studied L1551 IRS 5 outflow, which extends over $10'$ (0.4 pc), seven of the remaining eight sources are found to drive ^{12}CO 3–2 outflows over $\leq 1'$ (0.04 pc); only L1527 IRS has a well-developed outflow of some $3'$ (0.12 pc). Estimates are obtained for the outflow kinetic luminosity, $L_{\rm kin}$, and the flow momentum rate, $F_{\rm CO}$, applying corrections for line opacity and source inclination. The flow force $F_{\rm CO}$ is correlated with the envelope mass and with the 2.7 mm flux of the circumstellar disk. Only a weak correlation is seen with $L_{\rm bol}$, while none is found with the relative age of the object as measured by $\int T_{\rm mb}({\rm HCO}^+\, 3-2) dV / L_{\rm bol}$. These trends support the hypothesis that outflows are driven by accretion through a disk, with a global mass infall rate determined by the mass and density of the envelope. The association of compact HCO^+ emission with the walls of the outflow cavities indicates that outflows, in turn, influence the appearance of the envelopes. It is not yet clear, however, whether they are actively involved in sweeping up envelope material, or merely provide a low-opacity pathway for heating radiation to reach into the envelope.

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http://www.strw.leidenuniv.nl/~michiel/preprints.html

Accretion in the Early Kuiper Belt I. Coagulation and Velocity Evolution

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We describe planetesimal accretion calculations in the Kuiper Belt. Our evolution code simulates planetesimal growth in a single annulus and includes velocity evolution but not fragmentation. Test results match analytic solutions and duplicate previous simulations at 1 AU.

In the Kuiper Belt, simulations without velocity evolution produce a single runaway body with a radius $r_i \gtrsim 1000$ km on a time scale $\tau_r \propto M_0^{-1} e_0^x$, where M_0 is the initial mass in the annulus, e_0 is the initial eccentricity of the planetesimals, and $x \approx$ 1–2. Runaway growth occurs in 100 Myr for $M_0 \approx 10$ M$_{earth}$ and $e_0 \approx 10^{-3}$ in a 6 AU annulus centered at 35 AU. This mass is close to the amount of dusty material expected in a minimum mass solar nebula extrapolated into the Kuiper Belt.

Simulations with velocity evolution produce runaway growth on a wide range of time scales. Dynamical friction and viscous stirring increase particle velocities in models with large (8 km) initial bodies. This velocity increase delays runaway growth by a factor of two compared to models without velocity evolution. In contrast, collisional damping dominates over dynamical friction and viscous stirring in models with small (80–800 m) initial bodies. Collisional damping decreases runaway growth by factors of 4–10 relative to constant velocity calculations. Simulations with minimum mass solar nebulae, $M_0 \sim 10$ M_{earth}, and small eccentricities, $e \approx 10^{-3}$, reach runaway growth on time scales of 20–40 Myr with 80 m initial bodies, 50–100 Myr with 800 m bodies, and 75–250 Myr for 8 km initial bodies. These growth times vary linearly with the mass of the annulus, $\tau_r \propto M_0^{-1}$, but are less sensitive to the initial eccentricity than constant velocity models.

In both sets of models, the time scales to produce 1000+ km objects are comparable to estimated formation time scales for Neptune. Thus, Pluto-sized objects can form in the outer solar system in parallel with the condensation of the outermost large planets.

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

Cores and Cavities in NGC1333

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We present 1.3mm continuum and CS $J = 5 \rightarrow 4$ maps at 12" resolution of the NGC1333 star forming region. The area covered is $8' \times 6'$. The large-scale bolometer and CS maps delineate very nicely the large central cavity together with the cores situated in the surrounding compressed shell. In addition to the four dust cores IRAS4A-B, IRAS2 and SSV13, we discovered two fainter condensations, one of which is not associated with protostellar activity. All protostars are surrounded by extended low-emissivity envelopes and show indications of depletion of molecules onto grains. The continuum emission traces material entrained by the outflows powered by IRAS4A, IRAS2 and SSV13. The CS $J = 5 \rightarrow 4$ is observed in all dust cores. Apart from IRAS4, the CS emission peak is shifted with respect to the dust continuum. The large-scale dust emission mostly comes from material compressed around two cavities, whose walls are detected in the H_2 S(1) v= 1-0 line. These cavities seem to have been excavated by outflows from the neighboring protostars IRAS4 and SSV13, and are now expanding in the ambient medium. Taken together these new data suggest that the large cavity in NGC1333 grows by local action of stars forming in the compressed edge, each producing a local cavity which eventually overlap.

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Kinetic Energy Decay Rates of Supersonic and Super-Alfvénic Turbulence in Star-Forming Clouds

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We compute 3D models of supersonic, sub-Alfvénic, and super-Alfvénic decaying turbulence, with an isothermal equation of state appropriate for star-forming interstellar clouds of molecular gas. We find that in 3D the kinetic energy decays as $t^{-\eta}$, with $0.85 < \eta < 1.2$. In 1D magnetized turbulence actually decays faster than unmagnetized turbulence. We compared different algorithms, and performed resolution studies reaching 256^3 zones or 70^3 particles. External driving must produce the observed long lifetimes and supersonic motions in molecular clouds, as undriven turbulence decays too fast.

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Preprints: http://www.mpia-hd.mpg.de/MPIA/Projects/THEORY/maclow/papers/turb_prl/

The spectrum of the young star HD 100546 observed with the Infrared Space Observatory

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It is generally assumed that planets form in the dusty disks that surround young stars (Beckwith & Sargent 1996). The Infrared Space Observatory (Kessler et al. 1996) now enables us to determine the characteristics of these disks with unprecedented spectral resolution and signal-to-noise. We present here ISO spectra of the disk that surrounds the young star HD 100546. A remarkable variety of emission features of carbon- and oxygen-rich dust occurs. Most prominent are a series of emission features that can be attributed to silicates in crystalline form, mostly forsterite. In the interstellar medium and HII regions the silicate dust is mostly amorphous, but crystalline silicates are found in comets, meteorites and interplanetary dust particles. The forsterite features of HD 100546 are astonishingly similar to those observed in the ISO spectrum of Comet Hale-Bopp (Crovisier et al. 1997), strengthening the hypothesis that the disk around HD 100546 contains a huge swarm of comets (Grady et al. 1997). We argue that the crystallisation process occurs during the early evolution of the circumstellar disks of young stars and speculate about the formation of an Oort cloud around HD 100546.

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http://www.ster.kuleuven.ac.be/homepage/publications.html

Cluster-Forming Molecular Cloud Cores

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We model a turbulent cloud core ionized by cosmic rays, having Bonnor-Ebert condensations which are both critically stable and cut off from MHD waves in the core. We take these condensations to be precursors of stars in clusters. The model predicts that such condensations can exist in "massive" cores having FWHM line width ¿ 0.9 km s^{-1} and column density ¿ 1×10^{22} cm^{-2}, as is observed in cluster-forming cores in Perseus, Orion, and Cepheus, but cannot exist in the less turbulent, less opaque "low-mass" cores in Taurus, which have no associated clusters. In cluster-forming cores these condensations are predicted to have mass $\sim$1 $M_\odot$ and radius $\sim$0.03 pc, consistent with the mass and spacing of most young stars in clusters. Such critically stable, cut-off condensations may be identified by their small size and narrow spectral lines, if observed with sufficient sensitivity, spectral resolution, and angular resolution.

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Dynamics of Circumstellar Disks

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We present a series of 2-dimensional hydrodynamic simulations of massive disks around protostars. We simulate the same physical problem using both a 'Piecewise Parabolic Method' (PPM) code and a 'Smoothed Particle Hydrodynamic' (SPH) code, and analyze their differences.

The disks studied here range in mass from $0.05M_*$ to $1.0M_*$ and in initial minimum Toomre Q value from 1.1 to 3.0. We adopt simple power laws for the initial density and temperature in the disk with an isothermal ($\gamma = 1$) equation of state. The disks are locally isothermal. We allow the central star to move freely in response to growing perturbations. The simulations using each code are compared to discover differences due to error in the methods used. For this problem, the strengths of the codes overlap only in a limited fashion, but similarities exist in their predictions, including spiral arm pattern speeds and morphological features. Our results represent limiting cases (i.e. systems evolved isothermally) rather than true physical systems.

Disks become active from the inner regions outward. From the earliest times, their evolution is a strongly dynamic process rather than a smooth progression toward eventual nonlinear behavior. Processes that occur in both the extreme inner and outer radial regions affect the growth of instabilities over the entire disk. Effects important for the global morphology of the system can originate at quite small distances from the star. We calculate approximate growth rates for the spiral patterns; the one-armed ($m = 1$) spiral arm is not the fastest growing pattern of most disks. Nonetheless, it plays a significant role due to factors which can excite it more quickly than other patterns. A marked change in the character of spiral structure occurs with varying disk mass. Low mass disks form filimentary spiral structures with many arms while high mass disks form grand design spiral structures with few arms.

In our SPH simulations, disks with initial minimum $Q = 1.5$ or lower break up into proto-binary or proto-planetary clumps. However, these simulations cannot follow the physics important for the flow and must be terminated before the system has completely evolved. At their termination, PPM simulations with similar initial conditions show uneven mass distributions within spiral arms, suggesting that clumping behavior might result if they were carried further. Simulations of tori, for which SPH and PPM are directly comparable, do show clumping in both codes. Concern that the point-like nature of SPH exaggerates clumping, that our representation of the gravitational potential in PPM is too coarse, and that our physics assumptions are too simple, suggest caution in interpretation of the clumping in both the disk and torus simulations.

Accepted by the Astrophysical Journal

Preprints are available via anonymous ftp to pegasus.as.arizona.edu in the directory /pub/andy The file is disk.ps.gz. Warning: This file is quite large due to the inclusion of a number of large encapsulated postscript files.

Free-free Radiation from Dense Interstellar Shock Waves

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We present detailed calculations of the free-free emission behind shock waves in media where the postshock gas may be optically thick at radio frequencies. Using the Cox-Raymond numerical shock code (1985), we solve the free-free radiative transfer equation at frequencies of 1.5, 5 and 15 GHz for a family of planar shock models which cover a wide range of densities ($1000 \leq \mathrm{n}_0 \leq 10^9$ cm^{-3}) and shock velocities ($30 \leq V_0 \leq 300$ km/s). These models also predict how different preshock magnetic fields and viewing angles affect the overall free-free emission.

As the shock velocities and preshock densities increase, the free-free spectral indices generally rise from optically thin values (~ -0.1) and approach optically thick ones (~ 2.0). We find that for $V \geq 120$ km/s, the ionized precursor produced by the emergent postshock UV radiation can itself become optically thick to free-free radiation when the preshock density exceeds 10^6 cm^{-3}. We also find that for some combinations of shock parameters, the superposition of radiation from the precursor onto that of the postshock region can produce spectral indices exceeding 2.0. In addition, we find that magnetic fields can suppress the free-free radiation only if they are strong enough to lower the magnetosonic Mach number below 4 for $V \geq 100$ km/s.

An observer who knows the resolved angular sizes, fluxes and spectral indices of a thermal radio source can use our grids to determine the preshock density, shock velocity and viewing angle to the source. Possible applications include the determination of shock parameters for HH objects, shocked cloudlets and accretion shocks deep within molecular clouds. As an example, we use our results to predict shock parameters for HH 1-2 and several thermal radio sources in Cep A east. We find that the predicted shock parameters for HH 1 and 2 agree well with those inferred from optical line ratios and line profiles. Radio emission from sources in Cep A are explained reasonably well as arising from thermal radiation behind a dense, fast shock like one might expect from a stellar jet deeply embedded within the

molecular cloud core.

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Preprints available at http://spacsun.rice.edu/ parviz/contribs.html

Binary Stars in the Orion Trapezium Cluster Core

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We have obtained high angular resolution (0.13 arcsec FWHM) near-infrared images of the central $\sim 40'' \times 40''$ of the Trapezium Cluster, using a speckle holography technique which we describe in detail. A search for close binary systems was made in K_s (2.16 μm) and H (1.65 μm) mosaic images, in which 45 and 35 stars were detected respectively. The sensitivity limits for stellar detections are $K_s \simeq 14.8$ and $H \simeq 14.9$ over the whole mosaics, and $K_s \simeq 16.0$ and $H \simeq 15.9$ for those regions of the mosaics where most data were accumulated, thus potentially including objects with sub-stellar masses down to $\sim 0.04 M_\odot$. In total, 4 binary systems were identified with projected linear separations in the range of $0\farcs14$–$0\farcs5$ (63 AU–225 AU). The resulting binary fraction for low mass pre-main sequence stars is $5.9\% \pm 4.0\%$. This fraction agrees well with the binary frequency observed for main sequence field stars, but is lower by a factor of ~ 3 than the fraction found from observations of young stars in Taurus-Auriga over the same range of separations. The difference in binary frequency between the core of the Trapezium Cluster and the low mass, low stellar density dark cloud Taurus-Auriga is established at a statistical significance level of 96%, and suggests that binary frequencies are affected by the local star forming environment. We show that the massive Trapezium star θ^1 Ori A has a nearby companion separated by $\sim 0\farcs2$ (~ 90 AU). The location of this companion is coincident, within the positional uncertainties, with a non-thermal and variable VLA radio-source, which was previously associated with θ^1 Ori A itself. We give H photometry for 32 stars, K_s photometry for 43 stars, and present a color-magnitude diagram for the Trapezium core.

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

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The Star Formation Newsletter is available on the World Wide Web, where you can access it via the ESO Portal (http://http.hq.eso.org/eso-homepage.html). You can also access it through the University of Massachusetts Astronomy World Wide Web server, the URL for its home page is http://www-astro.phast.umass.edu/

Protostellar infall: modelling submm spectral line observations

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Ph.D dissertation directed by: Derek Ward-Thompson

Ph.D degree awarded: December 1997

I study the problem of how to identify, and measure the properties of infalling protostellar envelopes, through radiative transfer modelling of submillimetre spectral line observations. The physical concepts and assumptions used in radiative transfer modelling of rotational molecular lines are discussed. The observations of this thesis are modelled using an exact, non-LTE, spherically symmetric radiative transfer code (STENHOLM), which numerically solves the radiative transfer problem using the Λ-iteration method. A detailed description of the code is given, including a number of new modifications. To test the performance of the code, comparisons are shown between the line profiles produced by STENHOLM and independent analytical and numerical calculations.

Observations are presented of a sample of protostellar candidates (mainly Class 0 sources), in transitions of HCO^+, $H^{13}CO^+$, CS, CO, and $C^{18}O$. The HCO^+ and CS transitions preferentially trace high density gas, whereas CO traces a much wider range of gas densities. A complex dynamical picture emerges, involving infall, rotation, and outflow. Of the ten objects included in the sample, five show qualitative signatures of infall (i.e. blue-skewed line profiles) in the high critical density tracers, CS and HCO^+ . Of the remaining objects, four show either no signature of infall or conflicting signatures in different tracers, and one (L483) shows red-skewed line profiles, in direct conflict with the infall expectation. I examine the evidence that the line profiles of the HCO^+ and CS transitions observed towards each of the objects are confused by emission from outflows, by comparing wherever possible the morphology and centroid velocity gradients found in maps of these transitions with CO outflow maps. I find that the CS and HCO^+ submillimetre transitions, which are usually thought of as good tracers of protostellar envelope gas by virtue of their large critical densities, are often significantly contaminated by outflow emission.

For the three objects which show the strongest evidence for infall (NGC1333-IRAS2, IRAS 16293-2422 and Serpens SMM4) strong centroid velocity gradients are measured in the CS and HCO^+ maps. I examine whether these velocity gradients are caused by outflow or rotation, and conclude that in the case of NGC1333-IRAS2, the outflow dominates the velocity gradient, whereas there is strong evidence that the IRAS 16293-2422 and Serpens SMM4 velocity gradients are due to rotation. Both these latter objects show evidence for elongation of their envelopes perpendicular to the rotation axis, suggesting they may be partially centrifugally supported.

I examine the physical constraints which can be used to limit the number and range of parameters used in protostellar envelope models, and identify the turbulent velocity and tracer molecule abundance as the principle sources of uncertainty in the radiative transfer modelling. I explore the trends in the appearance of the predicted line profiles as certain key parameters in the models are varied. The formation of the characteristic asymmetric double-peaked line profile in infalling envelopes is discussed in detail, and some previous misconceptions concerning this problem are highlighted. Radiative transfer modelling is carried out on HCO^+ and CS observations of NGC1333-IRAS2 and Serpens SMM4, using the STENHOLM radiative transfer code. Adequate fits are found for most of the observed line profiles using plausible infall model parameters, and possible reasons for the discrepancies are suggested. The density and velocity profiles in the best fit models are **inconsistent with the Standard Model,** since for both objects modelled, the infall velocities appear further advanced than the Standard Model would predict, given the density profile. I find better agreement with a form of collapse which assumes non-static initial conditions than with a static singular isothermal sphere. I also find tentative evidence that the infall velocity is retarded from free-fall towards the centre of the cloud.

University of Cologne

Postdoctoral Position in mm-wave/Submm-Astronomy

The *I. Physikalisches Institut der Universität zu Köln, Germany*, invites applications for a postdoctoral research position in the field of millimeter and submillimeter astronomy. Our group operates the KOSMA-3m submm telescope near Zermatt/Switzerland, participates in the AST/RO South-Pole observatory, and makes use of a variety of radio, (sub)millimeter, and infrared facility observatories. Current areas of research include the structure of molecular clouds, their interface regions with atomic and ionized gas, their chemistry, star formation regions within the galactic disk, in the Galactic Center, and in external galaxies. In parallel, our group is involved in the development of instrumentation for ground-, airborne and space based astronomy: accousto-optical spectrometers, submm- to THz-mixer devices and heterodyne receivers. The scientific and technological preparation of new forthcoming projects has now started, including the preparation of instrumentation for and observations with the Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Far Infrared Space Telescope (FIRST).

The successful candidate should have an active record of several years experience in (sub)millimeter observational astronomy, and combine his/her astronomical interests with software and/or instrument development work. The position is initially rewarded for two years which can be renewed annually up to a maximum of five. Applicants must have a Ph.D. in physics or astronomy. To apply, please send a curriculum vitae, a publication list, and a summary of current research interests. Also, arrange for three letters of reference to be sent to: KOSMA, Prof. G. Winnewisser, I. Physikalisches Institut, Universität zu Köln, Zülpicher Strasse 77, D-50937 Köln, Germany. Applications received before 30th April 1998 will be assured of full consideration.

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The 3rd Cologne-Zermatt-Symposium
on

The Physics and Chemistry of the Interstellar Medium

September 22-25, 1998
Zermatt, Switzerland

We hope to address a substantial fraction of the astrophysics community active in interstellar medium research. With the recent exciting results from ISO and new advances in observing techniques, instrumentation, and theoretical modelling we forsee exciting presentations and a stimulating exchange of ideas. Over four days, the symposium will include invited review talks along with contributed talks and poster presentations. The major topics will be

- Star Formation in the Early Universe
- The ISM in External Galaxies
- Structure of the Milky Way
- Structure and Evolution of the ISM
- The ISM in Star Forming Regions
- Chemistry, Photochemistry, and Laboratory Astrophysics
- Observatories, Telescopes, and Instrumentation

At the end of the conference, a free visit to the KOSMA observatory will be arranged.

Members of the Scientific Organizing Comittee are:
L. Blitz, R. Booth, E. van Dishoeck, R. Genzel, M. Guélin, R. Kawabe, J. Martin-Pintado, K. Menten, P. Myers, T. Phillips, G. Tofani, D.A. Williams, G. Winnewisser

Local Organizing Comittee:
G. Winnewisser, J. Stutzki, C. Kramer, V. Ossenkopf, U. Corneliussen

For further information and registration, please visit the conference webpage at

http://www.ph1.uni-koeln.de/zermatt1998/ .

In case of additional questions, you can contact the local organizing comittee at
zermatt@ph1.uni-koeln.de, via telephone +49 221 470 3554 or fax +49 221 470 5162 or at
KOSMA, I. Physikalisches Institut, Universität zu Köln, Zülpicher Strasse 77,
D-50937 Köln, Germany

Deadline for registration and submission of abstracts: April 15, 1998.

Revised and Updated Announcement

NATO ADVANCED STUDY INSTITUTE

on

The Physics of Star Formation and Early Stellar Evolution

24 May - 5 June 1998

Knossos Royal Village Beach Hotel

Hersonissos (near Heraklion), Crete, Greece

The aim of this NATO Advanced Study Institute (ASI) is to provide a systematic overview and rigorous introduction to the fundamental Physics and Astronomy of star formation and early stellar evolution for graduate students and young researchers in these and related fields.

The format of this ASI will be modeled after the successful ASI on these same topics held in Crete in 1990. The Institute will consist primarily of a series of comprehensive review lectures given by an international group of distinguished researchers. A Special Seminar is also planned to cover topics of unusual interest which are either not covered in the main reviews or require a more in-depth treatment than permitted in the main reviews. Extensive time will also be devoted to poster sessions and informal discussion sessions. Participants will be strongly encouraged to contribute poster papers in the subject areas of the conference. Special Awards will be given to the best posters.

Among the topics to be covered in this ASI are:

The Physics of Molecular Cloud Structure and Evolution.
The Chemistry of Star Forming Clouds.
Cosmic Magnetism and Star Formation.
The Nature, Origin and Evolution of Embedded Star Clusters and OB Associations.
The Theories of Star Formation and Pre-Main Sequence Evolution.
The Nature of Protostars.
Masers in Star Formation.
The Origin and Evolution of Bipolar Outflows, Jets, and Circumstellar Disks.
Extra-Solar Planet Detection, and the Theory of Planet Formation.

Confirmed Lecturers and Seminar Speakers include:
Philippe Andre, Rafael Bachiller, Steve Beckwith, Claude Bertout, Adriaan Blaauw, Leo Blitz, Ed Churchwell, Cathie Clarke, David Hollenbach, Scott Kenyon, Nick Kylafis, Charles Lada, Elizabeth Lada, Telemachos Mouschovias, Geoff Marcy, Chris McKee, Phil Myers, Antonella Natta, Francesco Palla, Bo Reipurth, Anneila Sargent, Frank Shu, Ewine van Dishoeck, Erick Young, & Hans Zinnecker.

Directors:
Nick Kylafis (University of Crete) and Charles J. Lada (Smithsonian Astrophysical Observatory)

The site of the ASI, The Knossos Royal Village Hotel, is a major resort hotel on the beautiful north shore of Crete about 24 km east of Heraklion, Crete. All participants will be required to be present for the entire duration of the ASI.

TO SUBMIT AN APPLICATION please visit our WEB site:

http://www.mitos.com.gr/conf/starASI98/index.html
or email: mitos@stepc.gr

APPLICATION DEADLINE: 15 MARCH 1998
A color poster announcing the ASI can be obtained by anonymous ftp to:
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login: anonymous
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get creteposter.ps