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Abstracts of recently accepted papers

Explosive Ejection associated with Star Formation in Orion

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Tightly collimated outflows are often found associated with young stars, interacting with the ambient medium to produce shock-excited emission knots known as Herbig-Haro (HH) objects. Of two interpretations for HH objects one, ejection of a dense clump of material, has fallen from favour. More popular interpretations invoke the shocking of stationary blobs by a fast, low-density jet. We report the discovery of a complex of HH objects and associated wakes in the Orion Molecular Cloud—One that requires compact knots of material to have been ejected over a wide opening angle in a seemingly explosive event.

Accepted by Nature

Modeling of IR Emission of Interstellar Clouds

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A numerical model was developed to compute the penetration of heating radiation inside molecular clouds and the resulting IR emission of dust when thermal fluctuations of small dust particles is considered. It has been used to investigate physical conditions of some selected clouds heated either by the galactic diffuse Inter Stellar Radiation Field (ISRF) or receiving radiation from nearby young stars. The individuals clouds studied were selected among those showing short IRAS wavelengths Limb Brightening (LB) effect. The model used allows to quantify the abundance variations of the smallest dust components which are necessary, inside the clouds, to reproduce the spatial structure of the IR emission. For the clouds where IR brightness profiles can be used reliably down to the cloud center, it is found that the smallest dust particles must be present only in a halo surrounding the cloud. This conclusion is reached both for isolated clouds and nearby recently formed stars. The inner position of the halo is found to be at a visible extinction of about 0.5 mg independent of the external radiation field, indicating that some other physical parameters may be responsible for the halo. Several hypothesis are examined. The comparison with CO emission data also shows that a substantial amount of dust is present in the limb brightening region where no CO is observed with the current available sensitivity. The use of an IR emission model allow to determine the cloud density distribution in these regions.

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Angular Momentum Regulation in Low Mass Young Stars Surrounded by Accretion Disks

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This contribution examines the role played by circumstellar accretion disks in establishing the initial angular momentum in low mass pre-main sequence stars. ¿From study of a sample of 34 T Tauri stars with photometrically-derived rotation periods and spectral types later than K5, we find that the observed periods appear to be related to the presence or absence of an accretion disk. Those stars which we infer to be surrounded by accretion disks have rotation periods $P_{rot} > 4$ days with a most probable period $P_{rot} \sim 8.5$ days, while those stars which lack accretion disk signatures cover a wide range of rotation periods, from $1.5 < P_{rot} < 16$ days, including a significant number of objects with $P_{rot} < 4$ days.

This suggests the possibility that the "initial" angular momentum of a star is not established until it dissipates its circumstellar accretion disk. During the disk accretion phase, the stellar angular velocity appears to be regulated at a low value, countering the tendency of the star to spin up both from contraction toward the main sequence and from the accretion of inner disk material of high specific angular momentum. When the accretion disk is dissipated, this regulation mechanism will cease to function. At this point, the star is no longer maintained at a low angular velocity, but is "free" to conserve its angular momentum, and thus to increase its angular velocity in response to contraction and changes in moment of inertia. This hypothesis, combined with a spread in disk dispersal timescales, provides a context for explaining the observed distribution of stellar rotational velocities for stars on the zero age main sequence in young clusters.

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Optical and Near-Infrared Observations of S 140N

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Optical CCD images and polarimetry as well as near-IR observations of the molecular core S 140N are presented. The images reveal a reflection nebulosity associated with the young IRAS source 22178+6317. Two point-like sources are embedded in the reflection nebulosity. The near-IR colours indicate an IR excess characteristic of PMS objects. The CO outflow detected in the region is likely to be driven by these young objects. Four Herbig-Haro objects are detected in our images. This is the first detection of these kinds of objects in the S 140 molecular cloud. The HH objects are aligned in a scale of ≈2.5' (≈0.7 pc) and point to a faint star, located at the northern end of the brighter HH object. This star is therefore a suitable candidate to excite the HH objects and is likely to be a T-Tauri like star. In addition, the star is centered on a previously detected ammonia core and likely heats the high density gas. Finally, these data show that not only high mass stars, but also low mass stars have recently formed in the S 140 molecular cloud.

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CO Observations of the Lupus Dark Clouds

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An extensive mapping of CO (J=1-0) emission from the Lupus 2 dark clouds has been made. Complementary observations in CO (J=2-1) and ^{13}CO (J=1-0) over the central main cloud were obtained. The molecular gas motions are small over the entire cloud complex but asymmetric line profiles exist possibly due to the presence of two velocity components separated by about 1 km s^{-1} in the main cloud. The relative intensity of these components changes gradually over the main cloud. We have found no evidence for any molecular outflows in the region. In particular the molecular gas is quiescent over the extremely active T Tauri star RU Lupi with its associated imbedded infrared sources and the Herbig-Haro object HH 55 in the main cloud. From this certain constraints can be put on the mass loss from the star. We derive a mass of about 10 $M_\odot$ for the main cloud and estimate that a similar mass resides in two filaments northeast and west of this core in addition to two isolated cloudlets. We also report on a few CO observations made in the Lupus 3 dark clouds where a complex velocity pattern was found at one location.

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A Decade of Photometric Observations of Young Stars - with Special Comments on Periodicities

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We have collected photometric observations of 16 young stellar objects during 10 observing periods from 1981 to 1991. The photometry includes measurements with broad-band Strömgren uvby and standard UBVRIJHKL intermediate filters in addition to narrow-band Hα and Hβ filters. A large part of the material has been discussed elsewhere and the purpose of the present article is to publish all individual measurements, to comment on light curves and colour diagrams not presented before and to make a search for periodic light fluctuations. The material includes 8 classical T Tauri stars (CTTS), 5 weak-line T Tauri stars (WTTS), 2 post T Tauri candidates (PTTS) and 1 Herbig A*e* star. We have searched for periodic light variations in 15 of the stars, of which 7 have not been followed photometrically before. None of the CTTS shows distinct periods. On this basis and a literature survey published elsewhere we conclude that many announced periods are still doubtful. Many of these stars tend to brighten and fade on certain time-scales which can differ from time to time. We also arrive at the conclusion that nevertheless about 1/4 of the CTTS studied so far have well defined periods. All five WTTS show evidence of regular fluctuations of small amplitudes on time-scales of a few days but for 3 stars (San 1, Andrew 481, SZCha) the data base is too small for any definite conclusions to be drawn. The amplitudes of the variations increase with decreasing wavelength and rotational modulation of dark spots on the stellar surface is consistent with such variations. In this picture Sz 82 (Thèffi 12), with a period of 1.2 days, is a fast rotator with pronounced ultraviolet activity and X-ray emission. RY Lup is a well studied case with an established period of 3.75 days. It is a special case of WTTS since it carries a large infrared excess. One PTTS was followed over several nights but show no evidence of periodicity. For the Herbig A*e* star AB Aur no period can be announced at present even though one Fourier method based on CLEAN does indicate periods close to what has been found from spectral line variability.

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Upper Limits to the Detection of Ammonia from Protoplanetary Disks around HL Tau and L1551-IRS 5

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We present NH_3(1,1) and (2,2) observations of the young stellar sources HL Tau and L1551-IRS 5 using the VLA in its B configuration, which provides an angular resolution of $\sim 0\farcs4$ ($\sim$ 50 AU at 140 pc) at 1.3 cm wavelength. Our goal was to detect and resolve circumstellar molecular disks with radius of the order of 100 AU around these two sources. No ammonia emission was detected toward either of them. The 3σ levels were 2.7 mJy beam^{-1} and 3.9 mJy beam^{-1} for HL Tau and L1551-IRS 5, respectively, with a velocity resolution of $\sim$ 5 km s^{-1}. With this non-detection, we estimate upper limits to the mass of the proposed protoplanetary molecular disks (within a radius of 100 AU from the central stars) on the order of $0.02 \left[\frac{X_{\rm NH_3}}{10^{-8}}\right]^{-1} M_\odot$ for HL Tau and $0.1 \left[\frac{X_{\rm NH_3}}{10^{-8}}\right]^{-1} M_\odot$ for L1551-IRS 5.

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Emission Line Objects near R CrA

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New CCD images show additional emission line objects close to R CrA in the Corona Australis Cloud. Two faint knots, strong in [SII], are seen against the receding CO flow associated with R CrA. They are closely aligned with HH 104 A,B and R CrA and have thus been labelled HH 104 C,D. The position angle corresponds to that of the transient spike described by Hartigan and Graham 1987. HH 104 C,D lie on the edge of a diffuse patch of nebulosity, strongest in Hα. I suggest that this is illuminated by light scattered from R CrA in the direction of the receding CO flow. The emission line star 1-100 observed by Hartigan and Graham has a variable spectrum. The is a [SII] knot 7 arcsec W, 9arcsec N of this star. A change in the morphology of the HH 100 refelction nebula between 1973 and 1983 is noted.

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First Detection of CS(10-9) in Galactic Star Forming Cores

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We report the first measurements of the high-gas density tracing J=10-9 CS and $C^{34}S$ transitions towards 8 galactic star forming cores. With the J=10 level 160 K above ground, and critical densities for excitation of $\sim 10^{7.8}$ cm^{-3}, these lines provide unique information about the ultra-dense cloud cores next to the star forming regions which cannot be deduced from less excited levels. Comparison with lower rotational transitions reveals strong excitation gradients across the cores. The high intensity of the submm transitions requires densities $\geq 10^7$cm^{-3} if excited by collisions. However, because by selection our sources are closely associated with luminous embedded objects, we also investigate in detail the effect of IR pumping into the v=1 vibrational level on the v=0 rotational population.

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Radiative Transfer in a Clumpy Medium I: Analytical Markov Process Solution for an N-phase Slab

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The equation for the transfer of continuum photons in a multi-phase scattering medium, which obeys Markov mixing statistics, is solved for an externally illuminated slab geometry. The slab is assumed to consist of N distinct phases containing dust-grains which both absorb and isotropically scatter photons. The variation with position of the extinction coefficient and dust-grain albedo are modelled by an N-state Markov process, which together with a 'non-local transport approximation', allows us to calculate analytical general and 'effective homogeneous' solutions for the average radiation field in each phase as a function of depth into the slab. Numerical examples for 2 and 3-phase hierarchical media show the average radiation intensities inside the slab to be, in some cases, significantly enhanced by the inclusion of a third phase.

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Radiative Transfer in a Clumpy Medium II: the Mega-grains Approximation for 2-phase Models

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An approximate method is presented for describing the transfer of radiation inside a 2-phase medium. The medium is assumed to consist of spherical clumps, with uniform size and density, embedded in a more tenous interclump medium. The transfer of radiation is modelled by treating the clumps as large grains, or 'mega-grains', with absorption and scattering coefficients calculable from the properties of the dust-grains of which the clumps are composed. Numerical examples, for various 2-phase slabs, show that radiation intensities calculated in this way agree closely with those found by modelling the density variations as a 2-state Markov process.

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The Embedded Young Stars in the Taurus-Auriga Molecular Cloud I. Models for Spectral Energy Distributions

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We describe radiative transfer calculations of infalling, dusty envelopes surrounding pre-main sequence stars and use these models to derive physical properties for a sample of 21 heavily-reddened young stars ("protostars") in the Taurus-Auriga molecular cloud. The density distributions needed to match the far-infrared peaks in the spectral energy distributions of these embedded sources suggest mass infall rates similar to those predicted for simple thermally-supported clouds with temperatures of roughly 10 K. Unless the dust opacities are badly in error, our models require substantial departures from spherical symmetry in the envelopes of all sources, as in Terebey, Shu, & Cassen's rotating infall solutions. These flattened envelopes may be produced by a combination of rotation and cavities excavated by bipolar flows. Terebey, Shu, & Cassen's models indicate a centrifugal radius of roughly 70 AU for many objects if rotation is the only important physical effect, and this radius is reasonably consistent with typical estimates for the sizes of circumstellar disks around T Tauri stars.

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The Embedded Young Stars in the Taurus-Auriga Molecular Cloud II. Models for Scattered Light Images

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We describe near-infrared imaging observations of embedded young stars in the Taurus-Auriga molecular cloud. We find a large range in J–K and H–K colors for these class I sources. The bluest objects have colors similar to the reddest T Tauri stars in the cloud; redder objects lie slightly above the reddening line for standard ISM dust and have apparent K extinctions of up to 5 mag. Most of these sources also show extended near-IR emission on scales of 10–20", which corresponds to linear sizes of 1500–3000 AU. The near-IR colors and nebular morphologies for this sample and the magnitude of linear polarization in several sources suggest scattered light produces most of the near-IR emission in these objects.

We adopt the Terebey, Shu, & Cassen solution for an infalling, rotating protostellar cloud and use a two dimensional Monte Carlo radiative transfer code to model the near-IR colors and images for the embedded sample. Our results suggest mass infall rates that agree with predictions for cold clouds (T $\approx$ 10–20 K) and are generally consistent with rates estimated from radiative equilibrium models in a previous paper (e.g., $\dot{M} \approx 2$–$10 \times 10^{-6}\, M_\odot\, yr^{-1}$). For reasonable dust grain parameters, the range of colors and extinctions require flattened density distributions with polar cavities evacuated by bipolar outflows. These results support the idea that infall and outflow occur simultaneously in deeply embedded, bipolar outflow sources. The data also indicate fairly large centrifugal radii, $R_c \approx 100$ AU, and large inclinations to the rotational axis, $i \approx 60 - 90^\circ$, for a typical source. Our centrifugal radius estimates agree with the disk radii inferred for many T Tauri stars in the Taurus-Auriga cloud. Better maps of polarization and molecular outflows in these objects can test our inclination estimates.

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Detection of a 400 AU Disk-like Structure Surrounding the Young Stellar Object Z CMa

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We report observations of the pre-main sequence binary system Z CMa in the near-infrared L' (3.87μm) and M (4.75μm) bands up to the diffraction limit of the 3.6-m ESO telescope. These observations reveal the presence of an elongated emission region at P.A. $161^\circ \pm 8^\circ$ with length about $0.38 \pm 0.06''$ surrounding the double star system and likely centered on the infrared embedded component. The major axis of this disk-like structure is perpendicular to the large-scale jet associated with Z CMa. We suggest that the observed emission is due to illumination of the FU Ori disk by the infrared source.

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Properties of Jet-driven Molecular Outflows

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We present a critical review of the observed properties of molecular outflows from young stellar objects and show that these properties can be explained by a model in which the molecular flow is driven solely by a collimated jet. Many of the best studied outflows have several characteristics in common, including 1) bipolarity, 2) collimation, 3) partly empty lobes, 4) most material at low velocities, 5) extremely high velocity features and 6) average momentum directed nearly parallel to the axis of the flow, with small transverse components. From consideration of the conservation of vector momentum, we deduce that energy-driven flows cannot produce the observed distribution of the momentum direction. Outflows are therefore most likely driven by collimated jets with strongly cooling shocks at the point where they interact with the molecular cloud. If the ages of molecular outflows are $\sim 2 \times 10^5$ years, then the observed jets

have sufficient momentum flux to drive them, without invoking any other wind component.

We present a simplified analysis of the interaction between jets and molecular clouds and calculate the appearance of a jet-driven flow. This simple model reproduces many of the observed features, in particular the extremely high velocity features, which are associated with bow shocks. The simple model produces a flow which is too narrow and an age which is too low. However, there is evidence that jets wander with time, continuously accelerating the molecular material during many dynamical times. When this continuous acceleration is taken into account, jet-driven models produce a more realistic appearance.

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Fragmentation of Magnetized Filamentary Molecular Clouds with Longitudinal and Helical Magnetic Fields

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The dynamical instability of a self-gravitating magnetized filamentary cloud is investigated by means of a normal mode analysis. The density distribution in equilibrium is assumed to be a function of the radial distance from the axis, $\rho_0(r) = \rho_c (1 + r^2/8H^2)^{-2}$, where ρ_c and H are model parameters specifying the density on the axis and the length scale, respectively, and the magnetic field is assumed to have both longitudinal (z-) and azimuthal (φ-) components with strength $B_0(r) \propto \sqrt{\rho_0(r)}$. Our model filamentary cloud is unstable against both axisymmetric and non-axisymmetric perturbations. The growth rates and the eigenfunctions of the unstable perturbations are obtained numerically as a function of the strength and configuration of the magnetic field. The most unstable perturbation is axisymmetric and its wavelength in units of H is shorter when the ratio of the magnetic pressure to the gas pressure is higher. This means that the filamentary cloud fragments into pieces with an apparently shorter interval when the magnetic field is stronger. The motion induced by the most unstable perturbation also depends on the magnetic field. When the z-component of the magnetic field is stronger, the fragment produced by instability collapses faster in the z-direction than in the r-direction. We discuss the late stage of the fragmentation.

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The Temperature Profile of T Tauri Disks

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This paper proposes that T Tauri stars are three-component systems, formed by a star, its circumstellar disk and a tenuous, dusty envelope which surrounds both. The dust in the envelope scatters and reemits stellar light in the direction of the disk, which is therefore significantly hotter at large distance from the star than if direct heating alone is considered.

The overall behaviour of the disk temperature is very sensitive to the envelope properties. For example, for spherically symmetric envelopes, the whole observed range of spectral indices in the interval 5$\sim$100 μm, (4/3 to 0), can be accounted for by models with density in the envelope $\propto r^{-1}$ and values of τ increasing from 0 to $\sim$0.4.

In this context, stellar winds, disk winds and infall models are discussed. Only disk winds seem able to reproduce the observed flat TTS spectra.

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Fragmentation and Kinematics of the W49N Cloud Core

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A multitransitional study of the molecular cloud core W49N has been carried out in seven rotational lines of CS and $C^{34}S$, ranging from J = 3-2 to J = 10-9. The cloud core consists primarily of three dense clumps, of size 0.4 - 1.0 pc, which are arranged nearly linearly along an axis at position angle 56deg. The clumps' local densities are 2 - 6 $\times 10^6$ cm^{-3}, and their masses are in the range 2000-7000 $M_\odot$, for a total core mass of 1.1 - 1.7 $\times$ 10^4 $M_\odot$. The two outer clumps are receding with an LSR velocity of 12 km/s, while the central clump is moving at 4 km/s, indicating that two different molecular clouds are involved. Since the 12 km/s gas is closer to us, the two clouds must be converging upon each other. In addition, the centralmost CS clump is spinning rapidly in a direction counter both to galactic rotation, and to the direction inferred earlier from recombination line observations of the compact HII regions associated with W49N. The molecular gas kinematics are consistent with the hypothesis that the enhanced star formation rate in W49N is related to the passage of these two molecular clouds through our Galaxy's Sagittarius spiral arm. The two clouds have presumably been brought close together by orbit crowding in the spiral arm's potential minimum, and so the likely trigger mechanism for the burst of star formation seen in W49 is a cloud-cloud collision.

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Multiplicity and the Ages of the Stars in the Taurus Star Forming Region

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Ages for the pre-main sequence stars in the Taurus star forming region now known to be multiples are systematically younger than the ages of the singles. This seems to be an artifact. Overestimating the stellar luminosity in an unresolved multiple whose components are on Hayashi tracks produces an underestimate of the system's age. Until the astrophysical parameters of the components in the multiples become better known, the published age estimates for the single stars should be more accurate. Their average age is two to three times that of the multiples regarded as unresolved objects. Since most of the stars in the Taurus SFR are in multiples, the average age of the entire group of stars is 2 to 3 times older than previously thought. This result applies to both the strong and weak emission line pre-main sequence stars. The implications of a longer phase of pre-main sequence activity are discussed.

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Numerical Simulations of Protostellar Jets with Nonequilibrium Cooling. I: Method and Two Dimensional Results

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In a series of three papers, multidimensional time-dependent numerical simulations of the propagation of protostellar jets into both uniform and plane stratified ambient media are presented. For the first time these simulations combine a nonequilibrium treatment of optically thin radiative cooling with time-dependent hydrodynamics. Both two and three dimensional models are presented; synthetic emission maps and positions velocity diagrams are constructed in the latter case for direct comparison to observations.

This first paper concentrates on a description of the numerical algorithms needed to solve the coupled time-dependent hydrodynamics and nonequilibrium rate equation. A test problem based on the overstability of radiative shocks is detailed. Two dimensional models of protostellar jets computed with both time-dependent nonequilibrium cooling and time-independent cooling using the assumption of complete ionization are compared. Substantial differences in

the morphology of the jets in these two cases are noted, and are attributable to differences in the effective cooling rates between the two formalisms for the same model parameters. The general characteristics of previous studies of non-adiabatic jets are recovered including the dependence of the degree of collimation of the jet and the size of its cocoon on the cooling strength, and the formation and fragmentation of a thin dense shell at the head of the jet. Two and three dimensional models of pulsed protostellar jets are presented in Paper II of this series, while Paper III focuses on three dimensional simulations of steady jets. Accepted by Ap. J.

Numerical Simulations of Protostellar Jets with Nonequilibrium Cooling. II: Models of Pulsed Jets

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In this second of three papers, we present multidimensional time-dependent numerical simulations of the propagation of protostellar jets into a uniform ambient medium which utilize a nonequilibrium treatment of optically thin radiative cooling. This paper focuses on two and three dimensional models of pulsed jets in which the jet inlet velocity is assumed to be intrinsically variable. These models are motivated by recent observations which suggest temporal variability may account for knots of emission detected in the jet beam in several sources.

Our simulations show that large amplitude periodic velocity variations as required by observations produce pulses which quickly steepen into shocks. For each pulse two shocks are formed: an upstream shock (propagating more slowly than the jet velocity) which decelerates high velocity material as it collides with the pulse, and a downstream shock (propagating more quickly than the jet velocity) produced as the pulse sweeps up low velocity material ahead of it. We find the pressure in the postshock material located between these two shocks is substantial, and it not only causes the shocks to separate, but also ejects jet material laterly from the pulses. This combination causes the pulses to widen and decay in amplitude as they propagate. The effect of varying the pulse amplitude and frequency on the evolution is studied. In three dimensions, emission from the shock surfaces bounding the pulses produce well separated emission knots which move at the mean velocity of the jet and fade as the pulses decay. Dense, cooled gas which collects a the head of the jet undergoes nonaxisymmetric fragmentation by a variety of dynamical instabilities, leading to clumps and filaments of material. Synthetic position-velocity diagrams constructed from the three dimensional kinematics of the pulsed jet reveal emission knots and a distinctive "sawtooth" structure. Accepted by Ap. J.

The Contribution of Disks and Envelopes to the Millimeter Continuum Emission from Very Young Low–mass Stars

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We investigate the question of disk formation during the protostar phase. We build on the results of Keene & Masson (1990) whose analysis of L1551 IRS5 showed the millimeter continuum emission comes from both an unresolved circumstellar component, i.e. disk, and a more extended envelope/dense core. We model the dust continuum emission from the dense cloud core using the cloud–collapse models of Terebey, Shu & Cassen (1984) and show that dust emission from the dense core is important when measured with large single–dish telescopes at 1.3 mm, but nearly negligible with interferometers at 2.7 mm. Combining new 2.7 mm Owens Valley Interferometer data of IRAS–Dense cores with data from the literature we conclude that massive disks are also seen towards a number of other sources including L1448 IRS3 (IRAS 03225+3034), whose disk mass is estimated to be 0.5 $M_\odot$ (assuming $T_D = 40$ K, $\beta = 1.5$, and optically thin emission). However 1.3 mm data from the IRAM 30-m telescope for a larger sample shows that massive disks are relatively rare, occurring around perhaps 5% of young embedded stars. This implies that either massive disks occur briefly during the embedded phase or that relatively few young stars form massive disks. The median 1.3 mm flux density of IRAS–Dense cores in our sample is nearly the same as T Tauri stars in the sample of Beckwith et al. (1990). We conclude that the *typical* disk mass is not significantly higher during the embedded phase

than during the later T Tauri phase.

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Orion KL: Rotation or Two Clouds?

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The IRAM 30-m telescope has been used to obtain a fully sampled 29″ resolution map of the J=5−4 (K=0 to 3) lines of methyl acetylene (CH_3C_2H) in a $2' \times 4'$ region in OMC1. This map shows a number of clumps along the ridge of OMC1. The kinetic temperatures and CH_3C_2H column densities are derived at most positions using the rotation diagram method. Towards IRc2 and towards the positions of four peaks within the J=5−4 map, the J=13−12 (K=0 to 4) lines have been observed with the KOSMA 3-m telescope. The kinetic temperatures (30 to 50 K) and column densities from the J=13−12 lines are consistent with those of J=5−4 lines. Our analysis shows that the cloud consists of three clumps with velocities (from south to north) 6.5, 8, and 10 km s^{-1}. These clumps overlap near IRc2 and about 60″ south of IRc2.

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IRAS 21391+5802: A Study in Intermediate Mass Star Formation

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We present infrared and millimeter wavelength observations of the cold IRAS source 21391+5802 and its associated molecular core. Infrared observations at λ=3.5 μm reveal a heavily obscured, central point source which is coincident with a compact (<3800 AU) λ=2.7 mm continuum and $C^{18}O$ emission region. The source radiates about 310 $L_\odot$, primarily at far-infrared wavelengths, suggesting that it is a young stellar object of intermediate mass (3-5 $M_\odot$). The steeply rising spectral energy distribution and the large fraction (∼50%) of the system mass residing in circumstellar material imply that IRAS 21391+5802 is in an early stage of evolution (<5 x 10^5 years). The inferred dust temperature of ∼50 K toward the source compared to the ambient gas temperature of ∼23 K previously deduced from NH_3 observations indicates a temperature gradient in the core. A comprehensive model for the surrounding core of dust and gas is devised to match the observed dust continuum emission and multi-transition CS emission from this and previous studies. Assuming an $r^{-0.4}$ temperature gradient, we find an $r^{-1.5\pm0.2}$ density gradient consistent with that of a gravitationally evolved core and a total core mass of 380 $M_\odot$. The observed dust emission is most consistent with a $\lambda^{-1.5}$ to λ^{-2} dust emissivity law; for a λ^{-2} law, the data are best fit by a mass opacity coefficient of 3.6 x 10^{-3} cm^2 g^{-1} at λ=1.25 mm. Our model underestimates the observed λ=2.7 mm continuum emission from the central 5″; we attribute this to the presence of a circumstellar disk.

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Molecular Line Emission Models of Herbig-Haro Objects. II. HCO^+ Emission

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We present time-dependent models of the chemistry and temperature of interstellar molecular gas clumps that are exposed to the radiation from propagating stellar-jet shocks. The X-ray, EUV, and FUV radiation from the shock initiates ion chemistry and also heats the gas in the clumps. Using representative parameters we show that, on the shock transit time between the clumps, the abundances of the ionized molecular species that are produced in the clumps can exceed the values determined from steady-state models by several orders of magnitude. Collisional excitation by

the heated gas can lead to measurable line emission from several ionized species; as in previous investigations of X-ray irradiated molecular gas, we find that electron impacts contribute significantly to this process. We apply these results to the interpretation of the HCO^+ line emission that has already been detected in several Herbig-Haro objects (including HH 1-2, HH 34S, and HH 7-11). We demonstrate that this picture provides a natural explanation of the fact that the line intensity typically peaks ahead of the associated shock as well as of the reported low line-center velocities and narrow linewidths. We tabulate several diagnostic line intensities of HCO^+ and other molecular species that may be used to infer the physical conditions in the emitting gas.

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Meetings

Physical Chemistry of Molecules and Grains in Space

Dates: 6 – 10 September 1993

Venue: Mont Sainte-Odile, France

Organising Committee:

P.Brechignac, Y.Ellinger, S.Lfach, A.Leger, R.McCarroll, I.Nenner, E.Roueff

The development of new instruments for ground-based (IRAM, VLT, VLBI) and satellite (ISO, FIRST project) observations will continue to generate a wealth of new results on physical and chemical behaviour of matter in space. The extreme environmental conditions (dilution, temperature, radiation) under which chemical species are usually found in space give rise to a complex non-equilibrium dynamics involving exotic molecules, radicals and other materials. This provides challenging problems for theoretical and experimental scientists.
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Thesis Abstracts

30 Doradus in the Large Magellanic Cloud: The Stellar Content and Initial Mass Function

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Ph.D dissertation directed by: Catharine D. Garmany

Ph.D degree awarded: August 1992

I present *UBV* photometry for 2400 stars in the OB associations of 30 Doradus in the LMC, and new spectroscopic classifications for 54 stars including 23 O stars. The entire catalog (exclusive of the dense core cluster R 136) is photometrically complete to $V = B = 18$ mag and $U = 17$ mag, although the completeness magnitudes are fainter for regions with less nebular contamination.

From these data, I have determined the effective temperatures and bolometric magnitudes of the stars and placed them on the theoretical H-R diagram. Using stellar evolution models, I then bin the stars by mass to obtain the initial mass function (IMF), which is the number distribution as a function of mass. The IMF shows marked curvature, flattening out to lower masses, even for masses above which the photometry is complete. Best estimates of the IMF slope yield values of $\Gamma = -1.3$ to -1.5 for $\mathcal{M} \geq 12\mathcal{M}_{\odot}$, where the Salpeter slope is $\Gamma = -1.35$. However, there are indications that different regions of 30 Doradus have different IMF slopes, perhaps the result of sequential star formation effects.

Calculations of the Lyman continuum photon luminosity, $N_{\rm Ly}$, lead to the result that $\sim 3.2 \times 10^{51}$ photons s^{-1} are being produced by the observed stars in 30 Doradus. This is equivalent to the ionization luminosity of 440 O7 V stars or 77 O5 V stars. Less than 60% of this luminosity comes from the 150 stars with spectroscopic classifications, implying that there still remain a large number of OB stars yet to be observed spectroscopically. This, along with stellar evolution effects, could explain the IMF curvature and the apparent deficiency of stars in the most massive bins of the IMF.

For an ionization-bounded H II region, the Hα luminosity due to the Lyman continuum photons produced by the stars would be $L_{\rm H\alpha} \approx 4.5 \times 10^{39}$ erg s^{-1}. This value agrees with the luminosity determined from the observed Hα flux, but is a lower limit since the effects of W-R stars and the unresolved cluster of R 136 have not been included.

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