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Abstracts of recently accepted papers

Vortices in Circumstellar Disks

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We discuss the physics of vortices in the circumstellar disks associated with young stellar objects. We elucidate the basic physical properties of these localized storm systems. In particular, we consider point vortices, linear vortices, the effects of self-gravity, magnetic fields, and nonlinear aspects of the problem. We find that these vortices can exist in many different forms in the disks of young stellar objects and may play a role in the formation of binary companions and/or giant planets. Vortices may enhance giant planet formation via gravitational instability by allowing dust grains (heavy elements) to settle to the center on a short time scale; the gravitational instability itself is also enhanced because the vortices also create a larger local surface density in the disk. In addition, vortices can enhance energy dissipation in disks and thereby affect disk accretion. Finally, we consider the possibility that vortices of this type exist in molecular clouds and in the disk of the galaxy itself. On all of these size scales, vortices can produce long-lived structures which may correspond to observed structures in these systems.

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Magnetic Braking, Ambipolar Diffusion, and the Formation of Cloud Cores and Protostars: II. A Parameter Study

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The formulation of the problem of the formation of protostellar cores in self-gravitating, magnetically supported, rotating, isothermal model molecular clouds was presented in a previous paper, where detailed numerical simulations for two different model clouds were also discussed. In this paper, we study the effect of varying five dimensionless free parameters: the ratio $\widetilde{\rho}$ of external density and central density in a reference state (which is related simply to an initial equilibrium state), the initial radial length scale $\widetilde{l}_{\rm ref}$ of the column density of the cloud, the central angular velocity of the reference state $\widetilde{\Omega}_{\rm c,ref}$, the central neutral-ion collision time in the reference state $\widetilde{\tau}_{\rm ni,ref}$ (which is inversely proportional to the collapse retardation factor $\nu_{\rm ff} \equiv \tau_{\rm ff}/\tau_{\rm ni}$), and the exponent k in the relation between the ion and neutral densities $n_{\rm i} \propto n_{\rm n}^k$. In addition to the models previously presented, seven more models are investigated here. Different values $(1/1000 - 1/100)$ of the initial magnetic-braking efficiency parameter $\widetilde{\rho}(> 0)$ do not significantly affect the evolution; magnetic braking remains effective during the quasistatic phase, and ineffective during the (dynamic) collapse of the magnetically and thermally supercritical core. The initially very effective magnetic braking also means that the solution is insensitive to values of $\widetilde{\Omega}_{\rm c,ref}$. Different values of $\widetilde{l}_{\rm ref}$ yield qualitatively similar evolution, with smaller cloud sizes leading to slightly smaller core sizes. Increasing the value of $\widetilde{\tau}_{\rm ni,ref}$ leads to more rapid evolution and larger, more rapidly rotating cores. A smaller k leads to relatively more rapid evolution in the core and a better core-envelope separation. We also give an analytical explanation of the previously presented result, that the gravitational field acting on an infalling mass shell in the central region of a nonhomologously contracting thin disk increases as $1/r_{\rm m}^3$, where $r_{\rm m}$ is the Lagrangian radius of the shell.

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Studies of star formation in isolated small dark clouds. I. A catalogue of southern Bok globules: optical and IRAS properties

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A comprehensive list of small southern molecular clouds (globules) has been established from the survey of southern dark clouds of Hartley et al. Only the densest globules, and those with diameters less than 10 arcmin were included in the list. These are found to form an entirely complementary sample to that of Clemens & Barvainis in the northern sky.

In this and the following paper a detailed study of the clouds has been undertaken through an examination of their optical and IRAS properties, and radio observations of ammonia. The aim of the study has been to determine their physical characteristics, their role in the formation of low mass stars, and the physical mechanism which either triggers the star formation process, or stabilises the globules against collapse.

The globules are predominantly elliptical. There is some evidence that the apparent galactic latitude distribution of our globules (as well as that of the Clemens & Barvainis sample) is more highly concentrated towards the galactic plane than that of the large molecular cloud complexes identified through CO surveys. This suggests that there are very few high latitude globules, or that selection effects play a major role in defining the apparent distribution.

Of the 169 globules studied, 76 were found to have IRAS sources lying toward them (totalling 83 sources). The IRAS sample is dominated by cooler sources than the sample found to be associated with molecular cloud cores by Beichman et al., and predominantly exhibit the colours of embedded sources.

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A copy of this paper is available via the World Wide Web at: http://cfa-www.harvard.edu/~bourke/papers.html

Studies of star formation in isolated small dark clouds. II. A southern ammonia survey

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A study of the set of small, southern molecular clouds (globules) compiled by Bourke, Hyland & Robinson has been undertaken, through radio observations of ammonia using the Parkes 64 m telescope. The aims of the study are to determine the physical characteristics of the globules, their role in the formation of low mass stars, and the physical mechanism that triggers the star formation process, or stabilizes the globules against collapse. With these general aims in mind, the (1,1) and (2,2) inversion transitions of ammonia were surveyed in order to determine the densities, temperatures and masses of the globules.

Half of the globules were detected in ammonia, but only 6% of the detections were 'strong' ($T_a^* \geq 0.35$ K). Comparing the globule properties with those of Benson & Myers for cores within complexes, we find that the globules are less opaque and less dense, and are less active sites of star formation. Other properties are comparable. The Vela cometary globules were detected more readily in ammonia than the more isolated globules, and are more active star formation sites. These results suggest that the dense core's environment, in particular the presence of either a large external mass or of a significant stellar wind, plays an important role in initiating the star formation process.

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Star Formation in the Gemini OB1 Molecular Cloud Complex

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We have conducted a study of the global star formation activity in the Gem OB1 molecular cloud complex using a combination of molecular line, near–infrared, and far–infrared data. A global survey for CS(J=2–1) emission yielded 11 cores with masses $\geq$ 100 $M_\odot$. These cores are typically elongated along arcs and filaments previously found in a large scale ^{12}CO and ^{13}CO survey. Based on the morphology of the cores, the association of some filaments with optical HII regions, and comparison of the observations with models with expanding HII regions, we suggest that these massive cores have formed primarily in swept up shells of molecular gas. At least 8 and possibly 10 of the 11 cores are associated with star formation as traced by the distribution of IRAS point sources, and the 3 cores contained in our near–infrared imaging survey each contain a cluster of stars. The high frequency of star formation associated with the cores suggests that star formation in massive dense cores begins soon after the core is formed, and that new cores must be continually formed if star formation is to continue in the Gem OB1 complex. A systematic survey in CS of 58 IRAS sources with far–infrared colors characteristic of young stellar objects indicated that the more luminous IRAS sources tend to be associated with more massive cores. This correlation suggests that more massive cores generally form massive stars, although we cannot determine from these data if this is an environmental or statistical effect. Our near–infrared and CS results suggest that dynamical evolution of the clusters and destruction of the cores are important effects to consider when contrasting the properties of different regions. A qualitative model for the Gem OB1 complex is proposed to explain these observations in which the primary mechanism for the formation of the massive dense cores is through the external compression of the molecular gas. The dense cores will generally form clusters of stars that rapidly disperse after the dense core is dissipated. The continual production of dense cores is provided for by the constant interactions of the molecular gas with energetic phenomena in the immediate environment.

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Observation of Infrared and Radio Lines of Molecules toward GL 2591 and Comparison to Physical and Chemical Models

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We have observed rovibrational transitions of C_2H_2 and HCN near 13 μm in absorption against GL2591. We have marginally detected NH_3 and set upper limits on rovibrational lines of CH_4, CS, SO, and SiO. We have also observed rotational transitions at 0.6–3 mm of CS, HCN, H_2CO, and HCO^+. The rovibrational data were analyzed in comparison to the absorption line analysis of CO by Mitchell et al. (1989). Our data are consistent with the C_2H_2 and HCN absorption arising in the same warm (200 K) and hot (1010 K) components seen in CO, but we see little evidence for the cold (38 K) component seen in CO. The results can be explained by a model in which early-time gas-phase abundances are preserved on grain mantles and later released at high temperature. Analysis of the rotational lines indicates that these do not arise from the same gas as the rovibrational lines. Comparison of the two data sets shows that the rovibrational absorption of HCN must come from a region with a small angular extent (less than about 2–3 arcsec, or about 2000–3000 AU at a distance of 1 kpc) and a much higher (factor of 400) abundance. The rovibrational lines from higher J states (J about 20) indicate that the hot HCN deviates from LTE. A good fit is obtained for a density of about 3×10^7 cm^{-3}. Analysis of the rotational lines, which arise in the extended cloud around the source, shows that no single-density model can explain all the data. Models with density and temperature gradients do much better; in particular models with $n(r) \propto r^{-\alpha}$, with $\alpha = 1.5$, can reproduce the observed pattern of emission line strengths. Models with $\alpha = 1.0$ or 2.0 are less satisfactory. These models predict densities of 3×10^7 cm^{-3} at radii slightly smaller than, but similar to, the upper limits on the size derived above. The temperatures of the gas seen in the rovibrational lines are clearly higher than predicted from a similar extension of the temperature law, suggesting other sources of heating. Comparison of the radio and infrared data indicate that the line of sight to the infrared

source has an unusually low column density.

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H_2O masers without associated diffuse H II regions: an earlier evolutionary phase?

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In apparent contrast with the common belief that galactic H_2O masers are always found associated with H II regions, the majority (80%) of H_2O masers are without diffuse H II regions. The aim of this work is to confirm the lack of diffuse ionized gas around these masers, and to see if these sources represent a homogeneous sub-class in an earlier evolutionary phase in which a diffuse H II region has not yet formed. We present the results of a search for H89α (3 cm) hydrogen recombination line towards a sub-sample of 60 of these masers. The detection rate is very low: only 2 sources (3%) show recombination line emission. In order to explain this low detection rate, we have examined possible selection effects, such as sensitivity of the recombination line observations, or lack of ionized gas because of the low luminosity of the associated star. Although both effects can play some role, by no means can they account for the large number of masers without associated diffuse H II regions. The most probable answer is that masers form very early, much before the formation of a diffuse H II region, and spend most of their life in this evolutionary stage. The 20% positional agreement between H II regions and water masers found in low resolution (arcmin) surveys may indicate that maser emission continues for a fraction of the main-sequence life-time of the newly formed star. Alternatively (and more probably), this coincidence may reflect that more than one star-formation event (i.e. the formation of a new maser) occurs in a stellar cluster and that these are spread over an extended period, longer than that required by the first massive stars of the cluster to develop their own H II regions.

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IRAS selected Galactic star-forming regions II: water maser detections in the extended sample

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The results of the analysis of the occurrence of 22.2 GHz H_2O maser emission in a sample of 1409 IRAS sources north of declination -30^o associated with star-forming regions are presented. Our sample contains all the IRAS sources which satisfy Emerson criteria to select molecular cores associated with the earliest evolutionary stages of the star-forming process. In a previous paper we have reported the results of the observations of about one third of the sample. In the present paper the observations of the remaining IRAS sources are presented: 18 of them are newly detected maser sources.

The results show that 20% of all IRAS sources which satisfy also the Wood and Churchwell criteria have water masers. This is in accord with the assumption that these criteria can select objects connected with the early phases of the evolution of high-mass star-forming regions. Moreover, about one third of the whole sample selected according to Emerson criteria contains IRAS sources which are not associated with massive star-forming process, but probably with molecular cores in low-mass star-forming regions.

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High-Resolution Far-Infrared Observations of DR 21

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We present new, high angular resolution two-color maps of the compact H II region DR 21 at 50 μm and 100 μm made with the 0.91 m telescope of NASA's Kuiper Airborne Observatory (KAO). From the maps we estimate the total fluxes of DR 21 at 50 μm and 100 μm to be 1.5 $\times 10^4$ Jy and 3.8 $\times 10^4$ Jy, respectively.

1. A homogenous plane-parallel slab model (Model I) is assumed in order to derive dust temperatures and optical depths. This model implies that the dust in DR 21 has relatively small optical depths at 100 μm ($\tau_{100} \sim 0.1$) and its temperature ranges from less than 20 K to $\sim$ 50 K.

2. A second model is also presented (Model II): a spherical symmetric dust cloud surrounding an O6 star. We used the radiation transfer code developed by Egan, Leung & Spagna (1988). Our selection criteria for the best fit were based on the best match for both the energy distribution in the 50-1300 μm range and the 100 μm source profile. Assuming the dust properties reported by Mathis, Mezger, & Panagia (1983), and using a mixture of graphite (50% by number) and silicate (50% by number), the best fit to the observations in our modeling with this approach is a spherical dust cloud described by anouter radius of 2.0 pc, an inner radius of 0.1 pc, and a CONSTANT dust density distribution. Although this model provides a reasonable fit to the 50-1300 μm flux densities and a marginal fit to the 100 μm profile, the predicted FWHM profiles at 800 and 1100 μm are much broader than those observed with high angular resolution (15$''$ and 19$''$ beams, respectively) as reported in the available literature

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The Distribution of Warm Dust in the Star-Forming Region Cepheus A: Infrared Constraints

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We have obtained new, high angular resolution far-infrared (FIR) maps (at 50 and 100 μm) of the star-forming region Cepheus A and polarimetric images (1.65 and 2.2 μm) of the reflection nebulosity, IRS 6, associated with this young stellar object. From our FIR maps we calculate the dust temperature and optical depth at 100 μm. Cepheus A has moderate optical depths ($\tau_{100} \leq 0.3$) and its dust temperature ranges from 30 to 50 K. The two- dimensional map of the 100 μm optical depth indicates that there is a region of lower dust column density near the peak of the FIR emission. A radiative transfer code was used to model the available photometry and the FIR data of Cepheus A. A spherical dust cloud with a central young star was assumed, and the input parameters in this model were varied in order to reproduce: (a) the spectral energy distribution and (b) the high angular resolution profiles at FIR wavelengths. The model that gives the best fit to the observations requires a dust cloud of the following characteristics: R_{outer}=0.5 pc, R_{inner}=0.07 pc, τ_{100}=0.15, α=1.5, where R_{outer}, R_{inner}, τ_{100} and α are the outer radius, inner radius, optical depth at 100 μm and exponent of the power law in the emitting-dust density gradient: $n_d(r) = n_0(r/r_0)^{-\alpha}$. The inner radius used in this model (R_{inner}=0.07 pc) is similar in size to the "cavity" derived from the two-dimensional map of the dust optical depth at 100 μm. For small distances (r $\leq$ 0.15 pc) from the infrared peak a second density gradient is derived from the distribution of the near-infrared (NIR) polarization. In this inner region of the dust cloud, the NIR polarization indicates that the density of the scattering dust should remain constant or increase slightly with distance. Our results are consistent with current star formation theories: a young stellar object surrounded by an infalling envelope with a characteritic density distribution of :$n_d(r) \propto r^{-1.5}$, a circumstellar disk, and a cavity ($R_{inner} \sim 0.07$ pc) in which n_d is constant, created by the dispersal of the initial dust cloud by a strong stellar wind.

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Near-infrared imaging in H_2 of molecular (CO) outflows from young stars

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In an attempt to identify the molecular shocks associated with the acceleration of ambient gas by collimated outflows from young stars, we have imaged a number of known molecular (CO) outflows in H_2 v=1-0 S(1) and wide-band K. H_2 line emission is detected in all six sources:

1. In the L 1157, VLA 1623 and NGC 6334I outflows, bow-shaped H_2 features are observed coincident with or just ahead of (downwind of) peaks in the CO outflow maps.

2. In NGC 2264G, as well as a compact group of H_2 knots coincident with the blue-shifted CO peak, we see an extended H_2 filament that traces the northern edge of the red-shifted CO flow.

3. In the L 1641N and Haro 4-255 molecular outflows we see a close correlation between H_2 line emission features and peaks in the CO outflow maps.

In each outflow system, the H_2 probably results from shocks associated with the interaction of the flow with the ambient, molecular gas. A comparison of the H_2 data with CO outflow maps strongly suggests that *"prompt entrainment" near the head of a jet is the dominant mechanism for producing the CO outflows in at least some of these sources.* We are also able to account for the ratios of observed radiated energy (derived from H_2 v=1-0 S(1) flux measurements) to mechanical power in the CO outflows in at least half of the outflows with a very simple, strong, radiative shock model.

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The S 269 stellar cluster

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We present the results of an imaging observational study of the young cluster associated wtih the HII region S 269. Images of the region have been carried out at optical (RI and emission line) and near-IR (JHK and narrow L) wavelengths. The I image detects nearly 300 sources with a remarkable clustering towards the western lobe of the HII region and the surroundings of the ionizing stars. The K image (extending to a more reduced field) detects 100 sources again showing a clear clustering. 79 objects are identified as members of the S 269 young cluster, the rest of the objects remaining unidentified. Our results suggest that the stars detected in S 269 could form either a massive BA stellar cluster suffering high extinction, or a PMS low-mass stellar cluster in which a few massive stars have formed already. In addition, we briefly discuss the apparent magnitude distribution

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Sequential Star Formation in OB Associations: The Role of Molecular Cloud Turbulence

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Numerical simulations of shock propagation into a 2-dimensional, clumpy, turbulent cloud suggest that the average shock speed, v_s, approximately equals the square root of the ratio of the external pressure to the average preshock density, ρ_0, and that the average shocked layer density, ρ_s, approximately equals the product of ρ_0 and the square of the velocity ratio, v_s/v_{turb}, for postshock rms turbulent speed v_{turb}. A comparison is made between seven theoretical formulations for the shock speed; all differ slightly from each other and from the measured shock speed, but usually not by more than a factor of 1.5. The maximum postshock density is much larger than the average postshock density because of the clumpy postshock structure; the maximum is comparable to $\rho_0(v_s/v_{th})^2$ for postshock thermal speed v_{th}. These relations are useful for the interpretation of forced cloud motions and shock speeds in turbulent molecular clouds near HII regions.

Preshock clumps form self-consistently by supersonic turbulence compression in the initial preshock gas. As the shock moves into the cloud, these clumps are squeezed and collected into the compressed layer, and they merge into a few massive, clumpy, postshock cores. The cores should produce bright rims in a real HII region because they protrude slightly into the ionized gas. The escape velocity in a typical model postshock core is larger than both the internal core velocity dispersion and the shock speed. Such a core would collapse gravitationally and ultimately form a star cluster. Stars could also form earlier when the preshock turbulent clumps collide with each other inside the postshock layer, or when the clumps are squeezed by the high pressure shock. Thus there could be an age spread inside the triggered cluster equal to the entire age of the shock, although most of the stars will form when the massive postshock cores collapse. The separation between OB association subgroups should be related to the time for the embedded cluster to grow to such a large mass that the stellar pressures inside the core disperse the gas and halt further star formation.

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Photometric observations of pre-main sequence objects

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We present the observational data of a photometric monitoring of 24 pre-main sequence objects: T Tauri stars, Ae/Be Herbig stars and some unclassified objects. Observations were carried out from July 1988 to August 1992, using the UBV(RI)$_c$ system. Variability with time scales from days to years and amplitudes in the V band larger than 0.1 mag is found for a part of this sample. The analysis of the possible causes of this variability are discussed in separate papers (Fernández & Eiroa 1995a,b).

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Speckle Imaging Measurements of the Relative Tangential Velocities of the Components of T Tauri Binary Stars

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Over a five year period, we have used speckle imaging to monitor 20 T Tauri binary stars with separations ranging from 0.″09 to 1″ (13 to 140 AU). This project is aimed at detecting the relative motion of the component stars to ascertain whether or not the observed companions (1) are stellar in nature, as opposed to being HH objects, and (2) are gravitationally bound to the primary stars. These observations demonstrate that speckle imaging measurements of close binary stars' separations can be made with an accuracy of a few milliarcseconds. The majority of the observed systems show significant relative velocities which (1) are not consistent with the motion expected for HH objects, (2) are greater than the velocity dispersion of these star forming regions and thus are not the result of differential proper motion, and (3) are consistent with orbital motion. This is the first demonstration that these systems are physically bound. Furthermore, these relative velocity measurements provide dynamical evidence that the average total mass of these T Tauri binary stars systems is $\approx$1.7 $M_\odot$.

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The β Pictoris phenomenon among young stars. II. UV observations of the Herbig Ae star UX Orionis

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IUE spectra of the Herbig Ae star UX Ori reveal the presence of large amplitude light and color changes, which are an extension to shorter wavelengths of the "blueing" effect seen in the optical. At optical maximum the UV spectrum of UX Ori is dominated by heavy line blanketing from accreting circumstellar gas with velocities as high as +200 km s^{-1}. At minimum light, prominent mid-UV emission from Fe II and Mg II is present, and the overall spectrum closely resembles spectra of more heavily embedded Herbig Ae stars. Comparison of the UV and optical data for UX Ori suggest that single parameter ISM-like extinction curves do not fit the observed data near optical maximum light, when contamination by scattered circumstellar dust is minimized. The best fit to the UV color-magnitude diagram is for circumstellar extinction dominated by silicate grains with $a_{min} \geq 0.15$ μm, and with a power law distribution $n(a) = a^{-2}$, suggesting that both the particle size distribution and grain chemistry in the inner disk have evolved considerably from those characteristic of molecular clouds in the 2-3 Myr since the formation of UX Ori.

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The ratio $N(\mathrm{CO})/E(J-K)$ in local molecular clouds

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We have investigated the ratio of carbon monoxide column density to colour excess $E(J-K)$ of background field stars in the direction of three different local clouds: the Coalsack, Chamaeleon I (Cha I) and R Coronae Australis (R CrA). For these dark clouds a uniform set of colour excess values towards highly reddened background stars is available from the literature based on near-infrared photometry data. Using the 15-m Swedish-ESO Submillimeter Telescope (SEST), we have observed towards these background stars the ^{12}CO, ^{13}CO and C^{18}O $J = 1-0$ emission lines and, in a few selected directions, the $J = 1-0$ transition of C^{17}O. We have also derived the $N(\mathrm{CO})/A_{\mathrm{V}}$ ratio and, based on a range of assumed gas-to-dust-ratios, the $N(\mathrm{CO})/N(\mathrm{H_2})$ ratio. We find that the $N(\mathrm{CO})$ to $E(J-K)$ ratio varies from cloud to cloud: it is a factor of ~ 2 larger in Cha I and R CrA than in the Coalsack. Our results can be interpreted in two alternative ways: firstly that the $N(\mathrm{CO})/N(\mathrm{H_2})$ ratio is higher in active star forming regions (Cha I, R CrA, and L 1641) than in more quiescent regions without star formation (Coalsack) and secondly that the ratio $N(\mathrm{H_2})/E(J-K)$ changes from cloud to cloud and is higher in active star forming regions than in quiescent clouds.

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Disk Accretion and Mass Loss From Young Stars

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In this paper we investigate how mass outflows from young stars relate to circumstellar disks by analyzing spectroscopic data of 42 T Tauri stars that span a broad range of infrared excesses. We measure the optical excess continuum (veiling) in each star from high-resolution 4-m spectra, and extract forbidden line profiles uncontaminated by terrestrial night sky emission, photospheric absorption lines and telluric absorption lines.

The veiling fluxes combined with existing infrared photometry allow us to estimate reddenings and stellar luminosities for the first time for heavily veiled stars. The new estimates of the stellar luminosities of these objects indicate that the stars with the highest accretion rates are the youngest in the sample. There is a one-to-one correspondence between forbidden line emission, veiling, and near-infrared color excess among the stars in our sample; all disks around young stars which are both optically thick and extend inward to within a few stellar radii of the stellar surface are, in fact, accretion disks, and have forbidden line emission.

Residual forbidden line profiles of [O I] λ6300, [O I] λ5577, [S II] λ6731, and [N II] λ6583, represent a range of critical densities from 10^4 to 10^8 cm^{-3}. We have determined luminosities and line ratios for the two distinct velocity components in each of these forbidden lines. The high velocity component resembles a dense stellar jet, but requires more than a single shock to account for the observed line ratios. Luminosities of the high velocity component indicate mass loss rates of $\sim 10^{-8} - 10^{-10}$ M$_\odot$ yr^{-1} for most stars, and disk accretion rates derived from the veiling fluxes are $\sim 10^{-6} - 10^{-8}$ M$_\odot$ yr^{-1}. The mass outflow rates and mass accretion rates are correlated. The ratio of mass outflow rate to the mass accretion rate depends upon how the forbidden line luminosities are interpreted, but is probably $\sim$ 0.01 for most classical T Tauri stars.

The low velocity component originates in a region of higher density than the high velocity component, and is characterized by a small negative radial velocity (~ -5 km s^{-1}), possibly associated with a disk wind or magnetic accretion columns. The velocity shifts are largest for forbidden lines with the lowest critical density, suggesting that the low velocity component accelerates away from the surface of the disk. If the low velocity component arises from the surface of a disk in Keplerian rotation, then the observed profiles imply that the surface brightness of the disk decreases as $\sim$ r$^{-2.2}$.

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This paper is available as a compressed postscript file from the Dept. of Space Physics and Astronomy Preprint Server. The WWW address is **http://spacsun.rice.edu**

Sulphur monoxide in the galactic cirrus

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We report the discovery of the SO ($N_J = 1_0 \rightarrow 0_1$) line near 30 GHz with the MPIfR 100 m telescope in two dense cores located in the galactic cirrus clouds MCLD123.5+24.9 and MCLD126.6+24.5 The emission is quite intense and extends over several arcmin. Since the SO line is most likely optically thick, we can only derive a lower limit for the cloud averaged column densities $N(\mathrm{SO}) > 10^{13}\mathrm{cm}^{-2}$. Both cores have also been mapped in the ^{13}CO ($J = 3 \rightarrow 2$) transition using the KOSMA 3 m telescope. Applying an escape propability model to match the observed line strength of this transition and of already published ($J = 1 \rightarrow 0$) data gives column densities in the range 2.0 10^{15} cm^{-2} $\leq N(^{13}\mathrm{CO}) \leq$ 6.0 10^{15} cm^{-2} and volume densities in the range of 0.5 10^4 cm^{-3} $\leq n(\mathrm{H_2}) \leq$ 2.5 10^4 cm^{-3}. Comparison of the SO column densities with the H_2 column densities derived from these ^{13}CO or already published C^{18}O column densities gives a lower limit for the fractional abundance of $X(\mathrm{SO}) > 4\ 10^{-9}$.

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Nonaxisymmetric Secular Instabilites Driven by Star/Disk Coupling

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We determine conditions for the onset of nonaxisymmetric secular instabilities in polytropes with a wide range of angular momentum distributions using Lagrangian techniques, and we then calculate the growth rate of such instabilities when driven by the coupling of the perturbed star to a circumstellar disk. We use Lagrangian replacement vectors with azimuthal coordinate. The onset of secular instability in terms of the quantity $T/|W|$, the ratio of rotational kinetic energy to gravitational potential energy, is affected by both the compressibility and the angular momentum distribution of the polytrope. The largest effects arise as the angular momentum distribution is varied. For polytropic index $n = 3/2$, the onset of secular instability for the $m = 2$ mode (the bar mode), as determined by its neutral point, shifts from $T/|W| = 0.141$ to 0.093, while the $m = 5$ mode neutral point shifts from $T/|W| = 0.088$ to 0.031 over the range of angular momentum distributions we consider. The smallest critical $T/|W|$-values occur for the angular momentum distribution of a Maclaurin spheroid, as the polytropic index n is increased from 3/2 to 5/2, the neutral point for m =2 shifts from $T/|W| = 0.069$ to 0.78. The neutral points for the $m = 2$ and 5 for the Maclaurin sequence ($n = 0$) are 0.127 and 0.0629, respectively. As the angular momentum distribution becomes more peaked toward the equatorial radius of the polytropes, the critical $T/|W|$-values generally become less sensitive to the compressibility of the polytrope.

Star/disk coupling can drive the secular instability in systems where the star is surrounded by a massive disk. further, if the instability can grow to moderate amplitude, then the coupling can transport significant amounts of angular momentum from the star in to the circumstellar disk. We find that, for the particular case of rotating protostars during the accretion phase, the time scales can be short enough to remove angular momentum from the central star at a significant rate.

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Pre-Main Sequence Evolution in the Taurus-Auriga Molecular Cloud

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This paper analyzes optical and infrared photometry of pre-main sequence stars in the Taurus-Auriga molecular cloud. More than half of the stars in our sample have excess near-infrared emission. The near-infrared excesses correlate very well with other measures of activity, such as Hα emission, ultraviolet excess emission, millimeter continuum emission, and the presence of reflection nebulae and molecular outflows. The infrared colors and the ratio of far-infrared to bolometric luminosity display a smooth progression from the most deeply embedded protostars to optically visible T Tauri stars. Infalling envelope models account for the colors of protostars; simple disk models similarly reproduce the colors of many T Tauri stars.

Both the stellar birthline and a 10^5 yr isochrone provide a reasonable upper envelope to the luminosity distribution of optically visible stars in the HR diagram. Only a few stars in the cloud have apparent ages exceeding 2–3 $\times$ 10^6 yr, as derived from detailed stellar evolution calculations. The distribution of stars in the HR diagram indicates that the cloud has formed stars at a roughly constant rate for the past 1–2 $\times$ 10^6 yr. Analyses of the J and K luminosity functions support this conclusion. Within the uncertainties, the observed mass distribution for optically visible stars agrees with a Miller-Scalo initial mass function. Source statistics imply a lifetime of 1–2 $\times$ 10^5 yr for the typical protostar in Taurus-Auriga. There is no evidence, however, that these sources lie on the stellar birthline. Indeed, the protostellar luminosity function is essentially identical to the luminosity function derived for optically visible T Tauri stars in the cloud.

These results provide some support for the evolutionary sequence – embedded protostar $\rightarrow$ T Tauri star with a circumstellar disk $\rightarrow$ T Tauri star without a circumstellar disk – currently envisioned in standard models of low mass star formation. Source statistics and infrared color-color diagrams demonstrate that pre-main sequence stars develop bluer colors and display less evidence for circumstellar material with time. The data show little evidence, however, for the luminosity evolution expected along the proposed evolutionary sequence. Time-dependent accretion during the infall phase may sizes of circumstellar disks around T Tauri stars.

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Study of Structure and Small Scale Fragmentation in TMC1

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Large scale $C^{18}O$ maps show that the Taurus Molecular Cloud 1 (TMC1) has numerous cores located along a ridge which extends about 12' by at least 35'. The cores traced by $C^{18}O$ are about a few arcmin (0.1 - 0.2 pc) in extent, typically contain about 0.5-3 $M_\odot$, and are probably gravitationally bound. We present a detailed study of the small scale fragmentary structure of one of these cores, called core D, within TMC1 using very high spectral and spatial resolution maps of CCS and CS. The CCS lines are excellent tracers for investigating the density, temperature and velocity structure in dense cores. The high spectral resolution, 0.008 km s^{-1}, data consist mainly of single dish, Nyquist sampled maps of CCS at 22 GHz with 45$''$ spatial resolution taken with NASA's 70m DSN antenna at Goldstone. The high spatial resolution spectral line maps were made with the VLA (9$''$ resolution) at 22 GHz and with the OVRO millimeter array in CCS and CS at 93 GHz and 98 GHz, respectively, with 6$''$ resolution. These maps are supplemented with single dish observations of CCS and $CC^{34}S$ spectra at 33 GHz using a NASA 34m DSN antenna, CCS 93 GHz, $C^{34}S$ (2-1) and $C^{18}O$ (1-0) single dish observations made with the AT&T Bell Laboratories 7m antenna.

Our high spectral and spatial CCS and CS maps show that core D is highly fragmented. The single dish CCS observations map out several clumps which range in size from $\sim$45$''$ to 90$''$ (0.03 to 0.06 pc). These clumps have very narrow intrinsic linewidths, 0.11 to 0.25 km s^{-1}, slightly larger than the thermal line width for CCS at 10 K, and masses about 0.03 to 0.2 $M_\odot$. Interferometer observations of some of these clumps show that they have considerable additional internal structure, consisting of several condensations ranging in size from $\sim$ 10$''$ to 30$''$ (0.007 to 0.021 pc), also with narrow linewidths. The mass of these smallest fragments is of order 0.01 $M_\odot$. These small scale structures traced by CCS appear to be gravitationally unbound by a large factor. Most of these objects have masses that fall below those of the putative proto-brown dwarfs ($\leq$ 0.1 $M_\odot$). The presence of many small gravitationally unbound clumps suggests that fragmentation mechanisms other than a purely Jeans gravitational instability may be important for the dynamics of these cold dense cores.

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Detecting T Tauri disks with optical long-baseline interferometry

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We present synthetic images of disks around T Tauri stars. We calculate visibility curves in order to study the possibility of directly detecting thermal emission from T Tauri disks. Total fluxes of T Tauri disks are compared to the sensitivity of *VISA*, the interferometric sub-array of the European *Very Large Telescope*. We conclude that thermal emission from circumstellar disk around T Tauri stars is detectable with current or soon-to-be interferometric techniques at wavelengths longer than 2.2 μm.

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Submillimeter Continuum Observations of the T Tauri Spectroscopic Binary GW Orionis

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We have measured submillimeter fluxes from the classical T Tauri spectroscopic binary GW Orionis. Single-dish measurements were obtained at 350 μm, 450 μm, 800 μm, 850 μm, and 1100 μm with the James Clerk Maxwell Telescope, and an interferometric map (beam FWHM of 2.5$''$) was obtained at 1360 μm with the Owens Valley millimeter-wave array. The submillimeter luminosity of GW Ori is comparable to the largest yet found among T Tauri and Herbig Ae stars. The source is unresolved in our interferometric map implying that the emitting material is confined within a radius of 500 AU.

The source of the submillimeter emission must be circumbinary. In an optically thin, isothermal (150 K) approximation we place a lower limit of 0.3 $M_\odot$ on the mass of circumbinary material, with an uncertainty of at least a factor three due to opacity normalization. The confinement of the submillimeter emission within $\approx$ 500 AU leads us to conclude that the origin of the submillimeter luminosity is a circumbinary disk. These conclusions are independent of specific disk models. Using the pure-disk model for GW Ori of Mathieu *et al.* (1991), we find a disk mass of 1.5 $M_\odot$, again with an uncertainty of at least a factor three.

A disk mass of 1.5 $M_\odot$ is 40%–50% of the total stellar mass. The circumbinary disk would be expected to drive rapid evolution of both the orbital semi-major axis and eccentricity. The low-eccentricity orbit of GW Ori is in marked contrast to this prediction, possibly indicating that the disk surface density in the vicinity of the binary may be small. The dynamical stability of such a massive disk is not clear, but stable disks of smaller mass are within the measurement uncertainty.

We find the observations are well fit with a grain opacity $\kappa_\nu \propto \nu^\beta$ having an exponent $\beta = 2$ at submillimeter wavelengths. Somewhat smaller values of β would also be acceptable, but $\beta \approx 1$ does not reproduce the data well. If a disk mass greater than 1.5 $M_\odot$ is taken to be unstable and short-lived, then our adopted opacity normalization of Hildebrand (1983) and Pollack *et al.* (1994) is an approximate lower limit to the true value for the GW Ori disk.

The specific disk-shell model of Mathieu *et al.* (1991) cannot reproduce these submillimeter observations. More generally, the confinement of at least 0.3 $M_\odot$ within a radius of 500 AU with no evidence of extension to larger radii is problematic for origin of the submillimeter emission in an infalling envelope. Furthermore we have found that a single steady-accretion disk cannot reproduce the observed spectral energy distribution at both near-infrared and submillimeter wavelengths; a more luminous circumbinary disk is required to explain the large submillimeter luminosity.

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Evidence for ongoing star formation in the Carina nebula

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We present the first evidence that star formation is continuing in the molecular complex associated with the Carina nebula. CO observations in several isotopomers and transitions reveal a clumpy and dynamically complex structure in the molecular gas south of the OB association Trumpler 16. Super–resolution IRAS images of the region show a 1.1 10^4 $L_\odot$ point source (IRAS 10430–5931) in a molecular clump at the edge of the cloud complex. The IRAS colors are characteristic of deeply embedded young stellar objects. Through a comparison with a published [SII] photograph, we find that the clump is a bright–rimmed globule. The mass of the globule is 80 $M_\odot$, yielding a luminosity–to–mass ratio of $\sim$ 100 $L_\odot/M_\odot$. J, H and K'–Band imaging of the IRAS source shows a group of highly reddened stars and bright nebulosity. We argue on a statistical basis that some of the reddened stars must be embedded in the globule and are not background objects. Additionally, several of the reddened stars exhibit anamolous near–infrared colors which are typical of embedded pre–main sequence stars. The near–infrared images show that all apparent star formation is taking place near the rim, 0.5 pc from the peak in ^{13}CO(2-1) emission. This morphology is suggestive of star formation triggered by radiation driven shocks.

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Search for 6 cm Formaldehyde Masers in 22 Galactic Star-Forming Regions

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A search for 6 cm H_2CO (formaldehyde) masers in 22 Galactic star-forming regions has been carried out using the B configuration of the VLA. These observations have $2''$ angular resolution. The sensitivity ranges between 2 and 4 mJy beam^{-1}. No new H_2CO masers are detected. The paucity of these masers suggests that 1) their lifetimes are quite short, and/or 2) a narrow range of physical parameters is necessary for their formation. The known H_2CO maser source NGC 7538 was also observed. The line flux of one of its two components has tripled over a 15 year period.

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What Is Powering the Orion Kleinmann-Low Infrared Nebula?

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We used the Very Large Array to observe the Orion BN/KL region simultaneously at frequencies of 8.4 and 43.1 GHz with $0\rlap{.}''25$ resolution. At 8.4 GHz we detect a rich cluster of compact radio continuum sources, some of which are coincident with infrared sources while others do not have known infrared counterparts. At 43.1 GHz we observed continuum emission together with the $v = 1, J = 1 \rightarrow 0$ SiO maser line, allowing precise registration of radio continuum relative to SiO emission. We find that the radio continuum emission from one of the radio sources, I, coincides with the centroid of the SiO maser distribution. Our SiO maser maps show intricate velocity structure indicative of ordered motions that must have a rotating and expanding (or contracting) component. Since source I powers an SiO maser it must have a high luminosity, most likely exceeding $10^4\ L_\odot$. Precise astrometry shows that it does *not* coincide with the mid-infrared source IRc 2. Given that the radio emission from source I is not affected by dust extinction, it locates the central (proto)star powering the IRc 2 complex. This suggests that the location and morphology of the infrared emission from "IRc 2" is determined by inhomogeneities of the dust envelope surrounding the central star. Furthermore, this brings into question all previous luminosity estimates of IRc 2 and opens the possibility that other sources contribute significantly to the energetics of the Orion-KL region. In particular, we suggest that another infrared source, n, which is coincident with a peculiar double radio source, may be responsible for at least some of the energetic phenomena observed in the region.

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Complex Molecules in Sagittarius B2(N): The Importance of Grain Chemistry

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The complex molecules vinyl cyanide (CH_2CHCN), methyl formate ($HCOOCH_3$), and ethyl cyanide (CH_3CH_2CN) were observed in the Sgr B2 star-forming region with the BIMA millimeter wavelength array. A region with diameter <0.1 pc toward the Sgr B2(N) molecular core is found to be the major source of these molecules. Also, this source is coincident with continuum emission from dust and a center of H_2O maser activity. Ultracompact (UC) H II regions are located within 0.1 pc. Strikingly, none of these molecules is detected toward Sgr B2(M), a core located $1'$ south of Sgr B2(N). The existence of complex molecules, a large mass of dust, high velocity H_2O masers, and UC H II regions strongly suggest that the Sgr B2(N) region has just begun to form stars, while the absence of strong dust emission and large molecules suggest Sgr B2(M) is more evolved. The detection of large molecules coincident with continuum emission from dust supports the idea found in current chemical models that grain chemistry is of crucial importance for the formation of these molecules.

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Molecular outflows and star formation in the HL Tau stellar group

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^{12}CO(2-1) and ^{13}CO(2-1) observations of the HL Tau/HH 30 region are presented. These observations have high sensitivity and spatial resolution, and allow a large scale study of the kinematics of the gas in this complex stellar group. The main result is that HL Tau drives a powerful extended molecular outflow that has probably blown out of its parental core on its blueward side. The red part of the flow is currently pushing its way into the denser remaining core gas. The mass of outflowing gas is of the order of $0.17\,M_\odot$ with 2/3 of this mass in the red part of the flow. The outflow rate is very high: $10^{-5}\,M_\odot$, a value consistent with FU Orionis accretion rates. We also propose that the complex molecular outflow field that we have discovered is the result of several other molecular outflows that are possibly associated with the optical jets in this stellar group. We deduce from our data that the current constitution of this group consists of $3.6\,M_\odot$ in gas and $2.0\,M_\odot$ in stars, implying a high star formation efficiency which approaches 36%. We compute the gravitational energy of the core and find that the HL Tau system probably remains bound in spite of its current outflow activity.

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The Initial Stages of an HH Jet/Cloud Core Collision

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We present a study of the initial evolution of the collision of an HH (Herbig-Haro) jet with a dense molecular cloud core. A simple analytical model shows that for a wide range of angles of incidence of the jet, the interaction will result in the formation of a reflected, less well collimated jet beam. Two-dimensional numerical simulations of the interaction of jets from constant and variable velocity sources with high density clouds (i.e., with infinite cloud-to-jet density ratios) are used to check the simple analytical model, and also to show the effect of the jet/cloud collision on the evolution of the internal working surfaces (formed by the source velocity variability). Predictions of [S II] emission maps from these models are also discussed. Finally, we present numerical simulations of jet/cloud interactions with finite cloud-to-jet density ratios, and discuss the observational implications of these models.

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A study of the Orion cometary cloud L1616

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With its cometary appearance and a reflection nebula near its edge facing some bright Orion stars, the Lynd's cloud L1616 shows ample evidence for being affected by one or more of these massive stars. To estimate its mass and star formation efficiency as well as to determine if it is gravitationally bound, we mapped this cloud in J=1→0 transitions of ^{12}CO and ^{13}CO. It is found that the distribution of the emission in the line *wings* show clear evidence for substantial mass motions. Also, the "virial" mass of the cloud is found to be five times the actual cloud mass determined from the ^{13}CO column density map. It is argued that this cloud has abnormally high star formation efficiency and is possibly disintegrating. The morphology and the location of the cloud indicate that it is being affected by the star ϵ Orionis which is also possibly responsible for the cloud's unusual star formation efficiency. Over a range of values of the relevant parameters, the star is found to quantitatively satisfy the requirements of being the cause of the observed characteristics of the cloud.

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Sequential star formation in the Cepheus molecular cloud: the S155/Cepheus B interface

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In this paper we present new radio and near-infrared observations of a bright Hα knot located south-east of the Cepheus OB3 association, near the ionization front that divides the S155 diffuse H II region from the Cepheus B molecular cloud.

The arcsec resolution VLA radio continuum images reveal that the previously unresolved radio source # 9, coincident with the Hα knot, is composed of four distinct sources: an extended RIDGE and three smaller diameter components. From the radio continuum spectrum and the general morphology it is possible to deduce that the RIDGE represents an ionization front in the northern part of the Hα knot. The larger of the small–diameter components is a blister-type compact H II region, still partly bounded by high density molecular gas. Another one of these components, which is very weak, is found to be variable. The third source is definitely unresolved even at 0.4 arcsec resolution and has a non–thermal spectral index. In the latter two sources, the proximity to sources with strong NIR excess in the field suggests that they are not background objects but, most probably, the non–thermal emission of PMS stars.

Near-infrared J, H, and K observations of the same region with similar resolution have detected several objects, either inside the Hα knot or deeply embedded in the dust-cloud molecular-clump to the south of it. Three red sources (previously undetected even in I-band) are found to be close to the positions of the three small–diameter radio continuum sources. One of these is located at the center of the blister type H II region and clearly is produced by its highly obscured exciting star.

This miniature near-infrared stellar cluster (in terms of total extension, if compared to the size of the neighboring OB association or of the Cepheus B molecular cloud) may be the product of an outburst of star formation triggered by the compression of the Cepheus B molecular cloud by the ionization front produced by the brightest stars of the previous-generation OB association.

While the large-scale general morphology and the ionization balance of the S155/Cepheus B molecular cloud is dictated by the brightest members of the OB association, the energy for the far-IR emission from the region of the Hα knot and the heating of the adjacent molecular hotspot may come entirely from the stars of the newly–formed cluster, without the need of external input from the luminous stars of the OB association.

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The W3 core: masses, densities, sizes and kinematics

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The core of the W 3 molecular cloud has been mapped in a $3'' \times 2''$ region in the J=2−1 transition of $C^{18}O$ and the J=3−2 and J=5−4 transitions of $C^{34}S$ with angular resolutions of 11″, 17″ and 10″ respectively, using the IRAM 30-m telescope. The W 3 core consists of two regions separated by 75″ (=0.85 pc at 2.3 kpc). The region associated with W 3 IRS 5 has an average $v_{lsr} \approx -39$ kms^{-1} and a mass of 800 $M_\odot$. The other, more extended region associated with W 3 IRS 4 has an average $v_{lsr} \approx -43$ kms^{-1} and a mass of 1500 $M_\odot$. The IRS 4 region is resolved into four smaller clumps. One of these is close to, but not coincident with, the submillimeter continuum peak SMS 3; another

is very close to IRS 4 and SMS 2. The IRS 5 region is barely resolved into four clumps. There is a clump centered on IRS 5.

From the $C^{18}O$ data, the H_2 column densities of the clumps have been determined. From a Large Velocity Gradient analysis of the $C^{34}S$ 3−2/5−4 ratios the H_2 densities and masses were estimated; these are compared with general results from the virial theorem. Dynamics are investigated using velocity channel maps. Over a 70″ region in Declination, the v_{lsr} of the IRS 4 region changes from −42 kms^{-1} in the southern part to −46 kms^{-1} in the northern part. For the northern part of IRS 4, over 70″ in Right Ascension, there is a change from −41 kms^{-1} in the western part to −47 kms^{-1} in the eastern part. This velocity change is opposite to the sense of galactic rotation; the gradient is 9 $kms^{-1}parsec^{-1}$. For the IRS 5 region, there is a similar change in v_{lsr} with Dec., but only a small change with R.A. Considering the presence of a magnetic field of 100μG towards IRS 4 and the striking change in radial velocity, we speculate that "magnetic braking" dominates the dynamics in the IRS 4 region. Our $C^{18}O$ and $C^{34}S$ results are compared with the abundances of other molecular species and show that the IRS 4 and IRS 5 regions have distinctly different chemistry.

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Discovery of a Pre-Main-Sequence Spectroscopic Binary: V773 Tauri

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A series of spectra of V773 Tau obtained during a seven night observing run at Kitt Peak National Observatory (KPNO) in 1993 December revealed double-lined structure. A period of several weeks is indicated by those spectra, which are best fit by a K2 V plus K5 V model. Further observations in 1994 March at Penn State's Black Moshannon Observatory (BMO), 1994 December and 1995 January at KPNO, and three archival KPNO spectra from 1988 January and 1992 November constrain the period to be 51.075 ± 0.018 days. The orbit of V773 Tau is eccentric and is seen at moderately high inclination, but probably not high enough for eclipses to occur. HR diagram placement and recent calculations of pre–main-sequence evolution suggest a mass ratio of about 1.78. While highly uncertain, this is higher than the dynamical mass ratio, $q = 1.32 \pm 0.06$. It is suggested that VLBI structures previously reported may simply be emission from both stars and possible RS CVn-like interaction, rather than huge loop structures.

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The Density Structure in the Rosette Molecular Cloud: Signposts of Evolution

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We have analyzed the clumpy structure of the moderately dense, $n_{H_2} \simeq 10^3\,cm^{-3}$ gas traced by the $J = 1 \rightarrow 0$ lines of CO and ^{13}CO in the Rosette Molecular Cloud. Approximately 30% of the clumps are gravitationally bound; about 15% are virialized. The clumps that are not gravitationally bound appear to be bound by the pressure of the interclump medium which is largely atomic. The clumps in which star formation is known to be taking place tend to be the most massive clumps in the complex and are all virialized or very close to it. Column density profiles of the star forming clumps are steeper than for the pressure bound clumps, and are reasonably well described by a form $\rho(r) \propto r^{-2}$. The clump mass spectrum follows a power law, $dN/dM \propto M^{-1.3}$, similar to other GMCs. We argue that the mass spectrum of the clumps does not evolve into the stellar IMF, which originates instead within the individual clumps. The internal density of the clumps measured by ^{13}CO is found to be nearly independent of clump mass. The volume filling fraction of the clumps relative to the entire GMC is 8%; the mean density contrast between the clump and interclump gas is about 40. The clumps exhibit a gradient in velocity of $0.08\,km\,s^{-1}\,pc^{-1}$ over the face of the cloud complex, but the energy in this ordered motion is only a fraction of the overall kinetic energy of the cloud. The clump-to-clump velocity dispersion decreases with clump mass, $\sigma_v(c-c) \propto M^{-0.15}$, indicating that the clump

ensemble is dynamically evolved. An additional sign of the evolutionary state of the cloud is that the most massive clumps lie closest to the midplane of the complex. It is shown that clumps that are closer to the Rosette Nebula have greater star formation rates (per unit gas mass) than similar clumps further away. There are also gradients in clump excitation temperatures and mean densities with distance to the HII region. We discuss the implications of these observations for the formation of the molecular cloud from an atomic cloud, the evolution of the clump mass spectrum, and the formation of stars.

Accepted by the Astrophysical Journal

High Resolution Observations of $C^{18}O$ and 2.7 mm continuum toward NGC 2024

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NGC 2024 has been imaged in the $J = 1 - 0$ line of $C^{18}O$ and in the continuum at a wavelength of 2.7 mm with a spatial resolution of $\sim 10''$. The continuum images show four features found in previous studies. A 160 mJy point source coincides with the position of IRS 2. When the flux density at 2.7 mm is combined with those at 6 cm and 1.3 cm, we find that the flux density of this source depends on frequency, ν, as $\nu^{1.3}$.

The positions of the other three continuum sources agree very well with the positions of the 1.3 mm sources FIR 3, 5 and 6, given by Mezger et al. (1988, 1992). Combining the 2.7 and 1.3 mm flux densities, we find that flux density shows a dependence $\geq \nu^4$. Using our upper limits to the 2.7 mm continuum flux densities at the positions of FIR 1, 2, 4 and 7, we obtain a similar dependence.

$C^{18}O$ emission is found in 3 slightly extended regions. The two southern peaks are offset from the positions of FIR 5 and FIR 6. The northern peak is located $\leq 4''$ from the position of FIR 2. For the $C^{18}O$ clouds, H_2 column densities from the virial theorem give (CO/H_2) ratios of $\sim 10^{-5}$, about 10% of the normally used value.

Accepted by A&A

Dense Gas in the DR 21 Region: High Resolution Imaging of the NH_3 Inversion Lines

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Three arcsecond angular resolution images of the (J,K)=(1,1) and (3,3) inversion lines of NH_3 toward the DR 21 HII region are presented. There is absorption in the (1,1) line toward DR 21 and emission to the NW, NE, SW and S. The NH_3 region found in emission in the (1,1) line SW of DR 21 is likely the same cloud seen in absorption toward the HII region. If the emission and absorption regions are taken as one cloud, this is the most massive and largest near DR 21. In the (J,K)=(1,1) line this cloud shows a velocity gradient of 15km s^{-1} pc^{-1}. To the NE, low brightness continuum emission extends over a larger region and there is little NH_3. In the (1,1) emission line, filament-like NH_3 emission regions are elongated N-S >20 arcseconds; for most, the emission is almost unresolved in the E-W direction. In most cases these filaments have a position angle which is very close to that measured for the molecular cloud over >10 arcminutes. The NH_3 emission line delineates the location of the denser molecular gas. The presence of dense clouds S and SW of the continuum source and the sharp fall-off of the HII continuum intensity to the SW gives support to the notion that the expansion of the HII region is halted by dense neutral gas to the SW.

The structures traced by the (3,3) transition differ greatly from those found for the (1,1) line. Toward the HII region DR 21, there are several (3,3) emission maxima, two of which exhibit prominent negative velocity line wings. The (3,3) line traces the hotter shocked gas. Given the negative velocity wings, the morphology of the (3,3) line emission and the location of the NH_3 emission relative to the powerful outflow seen in vibrationally excited H_2 and other molecules, we conclude that the NH_3 represents the remnant material which has survived the powerful outflow. We estimate the

location of the outflow source assuming that this is located near the shocked gas midway between the two NH_3 (3,3) maxima with prominent negative velocity line wings.

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Studies of dense molecular cores in regions of massive star formation. III. Statistics of the core parameters

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We analyze further the observational data for dense cores in regions of high mass star formation (HMSF) obtained recently with the SEST and Metsähovi radio telescopes. The statistical distributions of the core sizes, masses, mean densities, CS line widths and CO temperatures are constructed. To reduce the influence of the selection effects we consider separately also a subsample which includes the cores located within 3 kpc from the Sun. The size distribution peaks sharply at its lower edge ($\sim$ 1 pc). The mass spectrum for $M \geq 1000$ $M_\odot$ can be fitted by the power law ($dN/dM \propto M^{-1.7}$ for the 3 kpc subset).

The galacto-centric dependences of these parameters in the range $R \approx 7 - 11$ kpc are investigated. There is a trend to a systematic decrease of the mean density of the cores with increasing galacto-centric distance.

We have attempted to investigate the radial dependences of some physical parameters in several cores which have a simple structure. The CS line areas drop rather quickly with r, corresponding to $r^{-1.5}$ to r^{-2}. The CS line widths decrease towards the core edges as well, sometimes below the $C^{34}S$ line width (measured at the CS peak position). The ratios of the CS and $C^{34}S$ line widths and intensities are described preferably by the models with density inhomogeneities in the cores.

We investigate the $L - \Delta V$ and $L - \bar{n}$ relationships for the CS cores. Although there is a trend for increasing line width with increasing size the correlation is very weak. There is in general a higher velocity dispersion in HMSF cores than in CO clouds and dense cores in dark clouds. We suggest that the $L - \bar{n}$ data imply an upper limit to the mean density depending on the size.

Accepted by Astron. Astrophys.

First Announcement

Herbig-Haro Flows and the Birth of Low Mass Stars

to be held 20 – 25 January 1997 in Chamonix, France

Scientific Organizing Committee:

Claude Bertout (France, Co-chair), Karl-Heinz Böhm (USA), Nuria Calvet (Venezuela), Max Camenzind (Germany), John Dyson (England), Suzan Edwards (USA), George Herbig (USA), Alex Raga (Mexico), Bo Reipurth (Chile, Co-chair), Luis Felipe Rodriguez (Mexico).

An application for this meeting to have status as an IAU Symposium has been submitted to the IAU Executive Committee.

Symposium Objective:

The study of low mass star formation processes has undergone an explosive development in recent years, and is among the fastest developing subjects of contemporary astrophysics. Herbig-Haro flows, in addition to being remarkable astrophysical laboratories of their own right, are now regarded as an essential part of the birth of a star. With this Symposium, we intend to provide a comprehensive overview of our present knowledge of Herbig-Haro flows, observationally as well as theoretically, to explore the latest results on the earliest stellar evolutionary stages, and to tie the outflow phenomena from young stars into the general understanding of how stars form.

General topics to be discussed:

- Properties and Physics of Herbig-Haro Flows
- Herbig-Haro Flows and Other PMS Outflow Phenomena
- Formation and Properties of the Driving Sources of HH Jets
- The Physics of Accretion/Ejection Events
- Collapse Models, Binary Formation, and Angular Momentum Loss
- Infalling Envelopes, Circumstellar Disks and Stellar Winds

Additional information will be presented in the Star Formation Newsletter as it becomes available. Calls for registration will come with the Second Announcement. Further inquiries and suggestions should be addressed to the two chairmen (bertout@gag.observ-gr.fr, reipurth@eso.org).

Postdoctoral Research Assistant
Molecular Line Astronomy

Applications are invited for an astronomer to contribute to an observational and interpretational based study of the physics and chemistry of molecular clouds and the Interstellar Medium.

The aims are to study the chemical, physical and dynamic structure of molecular cloud cores, with emphasis on the physics of photo dissociation regions and on sites of high-mass star formation. The current programme includes studies of the physical properties of neutral and atomic gas in these regions using submillimetre spectroscopy of molecular lines, interstellar chemistry, molecular outflow sources, structure and dynamics of high mass star formation regions, and is supported by time-dependent chemical modelling of ionisation fronts and clumpy clouds. Other areas of interest to group members include studies of the central region of the Galaxy; studies of the chemical abundances of warm dense molecular cores, especially trying to understand the anomalous molecular abundances in regions such as the Orion Molecular Cloud and other regions of high-mass star formation; studies of Bok and Cometary Globules; studies of the interstellar medium in other galaxies. There will be a wide range of new programmes starting up following the launch of ISO, ranging from planetary studies, through star formation and ISM chemistry, to galaxies. The PDRA will be expected to play a major rôle in collecting, analysing and interpreting the molecular line data, and to work in collaboration with other academic staff including Prof. Glenn White and Dr Peter Williams, on the observing, interpretation and modelling parts of the programme.

Applicants must have or be about to obtain a PhD, and should have observational experience in molecular line astronomy, although those with related expertise will be considered. Applicants may be expected to pass a high altitude medical test, suitable for working at Mauna Kea.

Informal enquiries may be made to Prof. G White, Department of Physics on 0171-975-5056 or by e-mail to G.J.White@qmw.ac.uk. Further details of the QMW astronomical research programmes are available on the Internet at world-wide-web URL: http://www.qmw.ac.uk/~ugap735/Astronomy.html

The appointment, for two and a half years in the first instance, will start from October 1st 1995, and is funded by a PPARC rolling grant, with a salary in the range £14,962 - £19,513 pa inclusive, depending on age and experience.

For further details and an application form please telephone 0171-975-5171 (24 hour answerphone). Completed application forms, along with the names and addesses of two referees, plus a detailed curriculum vitae and copies of all publications should be submitted by 19th June 1995 to the Recruitment Co-ordinator, Personnel Office, Queen Mary & Westfield College, Mile End Road, London E1 4NS.

New Books

Planetary Systems: Formation, Evolution, and Detection

Edited by Bernard F. Burke, Jürgen H. Rahe and Elizabeth E. Roettger

These are the proceedings of the First Internation Conference, held in Pasadena, California on December 8–10, 1992. Reprinted from Astrophysics and Space Science Volume 212, Nos.1-2, 1994.

Selected articles of particular interest for the star formation community:

T. Owen: The Search for Other Planets: Clues from the Solar System
V.S. Safronov & E.L. Ruskol: Formation and Evolution of Planets
G.W.Wetherill: Possible Consequences of Absence of "Jupiters" in Planetary Systems
S. Sasaki: Dust Blobs in the Solar Nebula-Primary Distended Atmosphere
B. Donn & J.M. Duva: Formation and Properties of Fluffy Planetesimals
R. Neuhäuser & J.V. Feitzinger: Radial Migration of Planetesimals
S. S. Kumar: Very Low Mass Stars, Black Dwarfs and Planets
C.A. Grady et al.: Detection of Accreting Circumstellar Gas around Weak Emission-Line Herbig Ae/Be Stars
M.R Pérez et al.: The Evidence for Clumpy Accretion in the Herbig Ae Stars HR 5999
P.S. Thé & F.J. Molster: Protoplanetary Dust Clouds in Disks of Herbig Ae/Be Stars
N.J. Evans et al.: Identification of a Collapsing Protostar
H. Beust et al.: Cometary-Like Bodies in the Protoplanetary Disk around β Pictoris
J. Bouvier et al.: Synthetic Images of Protoplanetary Disks around Young Stars
M. Clampin et al.: New Observations of the β Pictoris Circumstellar Disk with the JHU Adaptice Optics Coronograph
R. Ferlet et al.: Inner Part Observation of the β Pictoris Disk
A.I Sargent & S.V.W. Beckwith: The Detection and Study of Pre-Planetary Disks
S. Terebey et al.: Millimeter Continuum Measurements of Circumstellar Dust around Very Young Low-Mass Stars
P.G. Mezger: The Search for Protostars Using Millimeter/Submillimeter Dust Emission as a Tracer
Th. Henning & E. Thamm: Cold Dust around Chamaeleon Stars
C. Friedemann et al.: Cloudy Circumstellar Dust Shells around Young Variable Stars
J.E. Van Vleve et al.: 10-μm Images and Spectra of T Tauri Stars
N. Ohashi et al.: The Nobeyama Millimeter Array Survey for Protoplanetary Disks around Protostar Candidates and T Tauri Stars in Taurus

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Short Announcements

Five College Astronomy Ph.D. Theses available on WWW

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The Ph.D. theses from the Five College - University of Massachusetts Astronomy Department are now becoming available over the World Wide Web. The first thesis available, Herbig Ae/Be Stars: An Investigation of Molecular Environments and Associated Stellar Populations by Lynne A. Hillenbrand is now available. Postscript versions of the individual chapters are also available. Theses will be added as they are accepted by the department.

The URL for the home page of our thesis server is:

http://decoy.phast.umass.edu/

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.

The Star Formation Newsletter is available on the World Wide Web. You can either access it via the ESO Portal (http://http.hq.eso.org/eso-homepage.html) or directly in two ways: by issue number (http://http.hq.eso.org/star-form-newsl/star-form-list.html) or via a wais index (wais://http.hq.eso.org:2010/starform). 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/