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Abstracts of recently accepted papers

Chemically active outflow L 1157

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We present millimeter-wave maps of the L 1157 bipolar outflow in several molecular emission lines. The CO emission traces the bulk of the outflowing gas in the red and blue shifted lobes displaying a remarkable S-shaped symmetry indicating the presence of a precessing jet. We determine the physical characteristics of the CO flow and show evidence for 3 or 4 independent episodes of mass ejection from the source. Molecules such as C_3H_2 , N_2H^+ and DCO^+ are seen to be abundant only in the quiescent medium, and result to be the best tracers of the high-density core surrounding the driving source of the outflow. Other molecules (SiO, CH_3OH , H_2CO , HCN, CN, SO, SO_2) are abundant in the outflow lobes, but exhibit strong emission gradients. Multiline observations of some species indicate that these gradients are not simply due to excitation effects, but are caused by an actual stratification in the chemical composition of the shocked molecular gas. Shock tracers such as SiO, CH_3OH , and sulphur-bearing molecules result to be the most promising candidates as potential chemical clocks to study the evolution of outflows. The characteristics of the L 1157 outflow, when compared to those of other outflows from Class 0 sources, indicate that L 1157 is the prototype of a category of bipolar outflows around Class 0 protostars which we denominate “chemically active outflows”.

Accepted by Astronomy & Astrophysics

A turbulent MHD model for molecular clouds and a new method of accretion on to star-forming cores

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We describe the results of a sequence of simulations of gravitational collapse in a turbulent magnetized region. The parameters are chosen to be representative of molecular cloud material. We find that several protostellar cores and filamentary structures of higher than average density form. The filaments inter-connect the high density cores. Furthermore, the magnetic field strengths are found to correlate positively with the density, in agreement with recent observations. We make synthetic channel maps of the simulations and show that material accreting onto the cores is channelled along the magnetized filamentary structures. This is compared with recent observations of S106, and shown to be consistent with these data. We postulate that this mechanism of accretion along filaments may provide a means for molecular cloud cores to grow to the point where they become gravitationally unstable and collapse to form stars.

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<http://www.astro.cf.ac.uk/pub/Derek.Ward-Thompson/publications.html>

The Historical Variability of T Tau, RY Tau and RW Aur

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We present the historical light curve of T Tau derived from photographic plates in the Harvard College Observatory archives. We find that the optical light of T Tau varied by 2-3 (or more) magnitudes on time scales as short as a month prior to ~ 1917 , consistent with the results of Lozinskii (1949). Extreme light fluctuations of greater than 2 magnitudes abruptly ceased in the late 1910's and, to the best of our knowledge, have not repeated since this time. We compare the observed light variations of T Tau to the T Tauri stars RY Tau and RW Aur, whose light curves we also constructed from inspection of the archival plates. We find that variable extinction along the line of sight to the star is the most likely explanation for the observed light fluctuation of T Tau during the early part of the 20th century.

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preprint address: <http://www.ess.sunysb.edu/tracy/preprint.html>

Formation of massive stars by growing accretion rate

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We perform calculations of pre-main sequence evolution of stars from 1 to $85 M_{\odot}$ with growing accretion rates \dot{M} . The values of \dot{M} are taken equal to a constant fraction \tilde{f} of the rates of the mass outflows observed by Churchwell (1998) and Henning (2000). The evolution of the various stellar parameters is given, as well as the evolution of the disc luminosity; electronic tables are provided as a supplement to the articles. Typically, the duration of the accretion phase of massive stars is $\simeq 3 \cdot 10^5$ yr. and there is less than 10% difference in the time necessary to form a 8 or $80 M_{\odot}$ star. If in a young cluster all the proto-stellar cores start to accrete at the same time, we then have a relation $M(t)$ between the masses of the new stars and the time t of their appearance. Since we also know the distribution of stellar masses at the end of star formation (IMF), we can derive the star formation history $N(t)$. Interestingly enough, the current IMF implies two peaks of star formation: low mass stars form first and high mass star form later.

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<http://babbage.sissa.it/abs/astro-ph/0105054>

IRAS 11590–6452 in BHR 71 – a binary protostellar system?

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New AAT near-infrared and SEST $^{12}\text{CO } J = 2 \rightarrow 1$ observations are combined with existing ISO mid-infrared and ATCA cm radio continuum observations to examine the protostellar content of the Bok globule BHR 71. Together with observations of Herbig-Haro objects, these data show: (1) Two protostellar sources, IRS1 and IRS2, with a separation of $\sim 17''$ (3400 AU) are located within BHR 71. (2) Each protostar is driving its own molecular outflow. The outflow from IRS1 is much larger in extent, is more massive, and dominates the CO emission. (3) Both protostars are associated with Herbig-Haro objects and shock excited $2.122 \mu\text{m } \text{H}_2 v=1-0\text{S}(1)$ emission, which coincide spatially with their CO outflows. (4) IRS1 is associated with cm continuum emission, with a flat or rising spectrum which is consistent with free-free emission, a signpost of protostellar origin.

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preprints available at:

<http://cfa-www.harvard.edu/sfgroup/> (CfA Star Formation/ISM www page)

<http://cfa-www.harvard.edu/~bourke/>

Temperature effects on the 15-85- μm Spectra of Olivines and Pyroxenes

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Far-infrared spectra of laboratory silicates are normally obtained at room temperature even though the grains responsible for astronomical silicate emission bands seen at wavelengths $> 20 \mu\text{m}$ are likely to be at temperatures below $\sim 150 \text{ K}$. In order to investigate the effect of temperature on silicate spectra, we have obtained absorption spectra of powdered forsterite and olivine, along with two orthoenstatites and diopside clinopyroxene, at $3.5 \pm 0.5 \text{ K}$ and at room temperature ($295 \pm 2 \text{ K}$). To determine the changes in the spectra the resolution must be increased from ~ 1 to 0.25 cm^{-1} at both temperatures since a reduction in temperature reduces the phonon density, thereby reducing the width of the infrared peaks. Several bands observed at 295 K split at 3.5 K . At 3.5 K the widths of isolated single bands in olivine, enstatites and diopside are $\sim 90\%$ of their 295 K -widths. However, in forsterite the 3.5-K -widths of the 31- , 49- and $69\text{-}\mu\text{m}$ bands are, respectively, 90% , 45% and 31% of their 295 K widths. Due to an increase in phonon energy as the lattice contracts, 3.5-K -singlet peaks occur at shorter wavelengths than do the corresponding 295-K peaks; the magnitude of the wavelength shift increases from $\sim 0 - 0.2 \mu\text{m}$ at $25 \mu\text{m}$ to $\sim 0.9 \mu\text{m}$ at $80 \mu\text{m}$. In olivines and enstatites the wavelength shifts can be approximated by polynomials of the form $ax + bx^2$ where $x = \lambda_{pk}(295 \text{ K})$ and the coefficients a and b differ between minerals; for diopside this formula gives a lower limit to the shift. Changes in the relative absorbances of spectral peaks are also observed. The temperature dependence of λ_{pk} and bandwidth shows promise as a means to deduce characteristic temperatures of mineralogically distinct grain populations. In addition, the observed changes in band strength with temperature will affect estimates of grain masses and relative mineral abundances inferred using room-temperature laboratory data. Spectral measurements of a variety of minerals at a range of temperatures are required to fully quantify these effects.

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HST/NICMOS detection of a partially embedded, intermediate-mass pre-main-sequence population in the 30 Doradus Nebula

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We present the detection of an intermediate-mass pre-main-sequence population embedded in the nebular filaments surrounding the 30 Doradus region in the Large Magellanic Cloud (LMC) using HST/NICMOS. In addition to four previously known luminous Class I infrared “protostars,” the NICMOS data reveal 20 new sources with intrinsic infrared excess similar to Galactic pre-main sequence stars. Based on their infrared brightness, these objects can be identified as the LMC equivalent of Galactic pre-main sequence stars. The faintest LMC Young Stellar Objects in the sample have colors similar to T Tauri and have about the same brightness as T Tauri if placed at the distance of the LMC. We find no evidence for a lower-mass cut-off in the initial mass function. Instead, the whole spectrum of stellar masses from pre-main sequence stars with $\approx 1.5 M_{\odot}$ to massive O stars still embedded in dense knots appears to be present in the nebular filaments. The majority of the young stellar objects can be found to the north of the central starburst cluster R136. This region is very likely evolving into an OB association.

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Spectroscopic Diagnostics of Organic Chemistry in the Protostellar Environment

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A combination of astronomical observations, laboratory studies, and theoretical modelling is necessary to determine the organic chemistry of dense molecular clouds. We present spectroscopic evidence for the composition and evolution of organic molecules in protostellar environments. The principal reaction pathways to complex molecule formation by catalysis on dust grains and by reactions in the interstellar gas are described. Protostellar cores, where warming of dust has induced evaporation of icy grain mantles, are excellent sites in which to study the interaction between gas phase and grain-surface chemistries. We investigate the link between organics that are observed as direct products of grain surface reactions and those which are formed by secondary gas phase reactions of evaporated surface products. Theory predicts observable correlations between specific interstellar molecules, and also which new organics are viable for detection. We discuss recent infrared observations obtained with the *Infrared Space Observatory*, laboratory studies of organic molecules, theories of molecule formation, and summarise recent radioastronomical searches for various complex molecules such as ethers, azaheterocyclic compounds, and amino acids.

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<http://www.strw.leidenuniv.nl/~pascale/publications.html#reviews>

Biomolecules in the Interstellar Medium and Comets

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We review recent studies of organic molecule formation in dense molecular clouds and in comets. We summarise the known organic inventories of molecular clouds and recent comets, particularly Hale-Bopp. The principal chemical formation pathways involving gas phase reactions, as well as formation by catalytic reactions on grain surfaces or through dust fragmentation, are identified for both dense clouds and cometary comae. The processes leading to organic molecules with known biological function, carbon chains, deuterium fractionation, HNC and S-bearing compounds are described. Observational searches for new interstellar organics are outlined and the connection between observed interstellar organics and those detected in comets Hale-Bopp and Hyakutake are discussed.

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<http://xxx.lanl.gov/abs/astro-ph/0104416>

A Two-Step Initial Mass Function: Consequences of Clustered Star Formation for Binary Properties

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If stars originate in transient bound clusters of moderate size, these clusters will decay due to dynamic interactions in

which a hard binary forms and ejects most or all the other stars. When the cluster members are chosen at random from a reasonable initial mass function (IMF), the resulting binary characteristics do not match current observations. We find a significant improvement in the trends of binary properties from this scenario when an additional constraint is taken into account, namely that there is a distribution of total cluster masses set by the masses of the cloud cores from which the clusters form. Two distinct steps then determine final stellar masses – the choice of a cluster mass and the formation of the individual stars. We refer to this as a “two-step” IMF. Simple statistical arguments are used in this Paper to show that a two-step IMF, combined with typical results from dynamic few-body system decay, tends to give better agreement between computed binary characteristics and observations than a one-step mass selection process.

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Energetic and thermal processing of interstellar ices

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Our current knowledge on the chemical composition of interstellar ices is summarised with respect to the possible contribution of energetic photons and particles to their observed state. We describe the inventory of astronomical ices as determined by infrared observations from the Infrared Space Observatory ISO and laboratory spectroscopy. Sources of radiolysis, UV photolysis, and ice heating are then discussed in the context of the chemical state of material in dense molecular clouds and in protostellar cores. Through specific examples we show how energetic processing can explain the observed solid state characteristics of several key molecules: CH₃OH, CO₂ and OCN⁻. We also discuss the gaseous and solid-state photochemistry of the first organic acid detected in interstellar ices, HCOOH.

JGR-Planets, in press

<http://www.strw.leidenuniv.nl/~pascale/publications.html#reviews>

Tracing the Mass during Low-Mass Star Formation. II. Modelling the Submillimeter Emission from Pre-Protostellar Cores

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We have modeled the emission from dust in pre-protostellar cores, including a self-consistent calculation of the temperature distribution for each input density distribution. Model density distributions include Bonnor-Ebert spheres and power laws. The Bonnor-Ebert spheres fit the data well for all three cores we have modeled. The dust temperatures decline to very low values ($T_d \sim 7$ K) in the centers of these cores, strongly affecting the dust emission. Compared to earlier models that assume constant dust temperatures, our models indicate higher central densities and smaller regions of relatively constant density. Indeed, for L1544, a power-law density distribution, similar to that of a singular, isothermal sphere, cannot be ruled out. For the three sources modeled herein, there seems to be a sequence of increasing central condensation, from L1512 to L1689B to L1544. The two denser cores, L1689B and L1544, have spectroscopic evidence for contraction, suggesting an evolutionary sequence for pre-protostellar cores.

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Preprints available from <http://peggysue.as.utexas.edu/yshirley/research.html>

or <http://xxx.lanl.gov/abs/astro-ph/0104238>

Filamentary structure and helical magnetic fields in the environment of a starless dense core

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The environment of L1512, a starless dense core, has been mapped at high angular resolution in the $^{12}\text{CO}(J=2-1)$ line over more than 1 pc and a few positions observed in the $^{12}\text{CO}(J=3-2)$ and $J=4-3$ lines. The gas outside the dense core is structured in several filaments, roughly 1 pc long and ~ 0.1 pc thick, converging at the dense core position. Small longitudinal ($\sim 1 \text{ km s}^{-1} \text{ pc}^{-1}$) but large transverse (up to $8 \text{ km s}^{-1} \text{ pc}^{-1}$) velocity gradients are observed. Remarkably, the transverse gradients can be seen to change sign periodically along at least one of the filaments. Thus, there are oscillations in the toroidal velocity within the filaments which may be a signature of a magneto-hydrodynamical instability developing in filaments permeated by a helical magnetic field. In the case of L1512, according to the analysis of Fiege & Pudritz (2000), the growth rate of the instability is low, corresponding to a timescale of the order of a Myr. We deduce from the wavelength of the oscillations that the toroidal component of the magnetic field dominates the poloidal component. The toroidal component helps confine the filaments which are not otherwise confined, either by self-gravity ($m/m_{\text{vir}} \sim 0.2$) or by the pressure of the galactic HI layer or external turbulent pressure. We find that the velocity gradients in the vicinity of the dense core provide an estimate for an upper limit to the accretion rate onto the dense core of $\dot{M} = 4 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$. For the gas characteristics in the filaments, we find that a broad range of density and temperature is allowed for the gas, between $n_{\text{H}_2} = 2 \times 10^3 \text{ cm}^{-3}$ for the coldest case ($T_k = 20 \text{ K}$) down to $n_{\text{H}_2} = 180 \text{ cm}^{-3}$ for the warmest ($T_k = 250 \text{ K}$).

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Molecular Depletion and Thermal Balance in Dark Cloud Cores

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We analyze the effects of molecular depletion on the thermal balance of well-shielded, quiescent dark cloud cores. Recent observations of significant depletion of molecules from the gas phase onto grain surfaces in dark clouds suggest the possibility that the gas phase cooling in these regions is greatly reduced, and consequently that gas kinetic temperatures might be increased. We reexamine cooling and heating processes in the light of possible molecular depletion, including the effect of coupling between the gas and the grains. At densities $\leq 10^{3.5} \text{ cm}^{-3}$, the gas temperature can be significantly increased by depletion of coolant species without significantly affecting the dust temperature, due to the relatively weak dust-gas coupling. At higher densities, this coupling becomes sufficiently rapid to overwhelm the effect of the reduced gas-phase cooling, and depletion has little effect on the gas temperature while raising the dust temperature $\simeq 1 \text{ K}$. The result is that depletion at densities $\geq 10^{4.5} \text{ cm}^{-3}$ can proceed without being evident as an enhanced gas temperature or without self-limiting due to an increase in the dust temperature increasing the desorption rate. This is consistent with observations of depletion in cold, dense regions of quiescent molecular clouds. It also suggests that depletion in moderate density regions can increase the thermal gas pressure, effectively enhancing the confinement of denser portions of molecular clouds and possibly accelerating the collapse of cloud cores.

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Disk Frequencies and Lifetimes in Young Clusters

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We report the results of the first sensitive *L*-band survey of the intermediate age (2.5 – 30 Myr) clusters NGC 2264, NGC 2362 and NGC 1960. We use *JHKL* colors to obtain a census of the circumstellar disk fractions in each cluster.

We find disk fractions of $52\% \pm 10\%$, $12\% \pm 4\%$ and $3\% \pm 3\%$ for the three clusters respectively. Together with our previously published *JHKL* investigations of the younger NGC 2024, Trapezium, and IC 348 clusters, we have completed the first systematic and homogenous survey for circumstellar disks in a sample of young clusters that both span a significant range in age (0.3 – 30 Myr) and contain statistically significant numbers of stars whose masses span nearly the entire stellar mass spectrum. Analysis of the combined survey indicates that the cluster disk fraction is initially very high ($\geq 80\%$) and rapidly decreases with increasing cluster age, such that half the stars within the clusters lose their disks in < 3 Myr. Moreover, these observations yield an overall disk lifetime of ~ 6 Myr in the surveyed cluster sample. This is the timescale for essentially all the stars in a cluster to lose their disks. This should set a meaningful constraint for the planet building timescale in stellar clusters. The implications of these results for current theories of planet formation are briefly discussed.

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SiO in G34.26: outflows and shocks in a high mass star forming region

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We have looked for SiO emission as evidence of shocks in the high mass star formation region G34.26+0.15. JCMT, VLA and FCRAO observations show that SiO emission is widespread across the region. The SiO emission highlights a massive, collimated outflow and other regions where stellar winds are interacting with molecular clumps. As in other star forming regions, there is also SiO at ambient velocities which is related to the outflow activity. No strong SiO abundance enhancement was measured in either the outflow or the low velocity gas, though abundances up to 10^{-8} are possible if the SiO is locally enhanced in clumps and optically thick. SiO emission is not detected from the hot core itself, indicating either that SiO is not strongly enhanced in the hot core or that column densities in the region where grain mantle evaporation has taken place are low. In line of sight spiral arm clouds, we measure a SiO abundance of $0.4\text{--}2 \times 10^{-10}$, consistent with previous estimates for quiescent clouds.

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preprints at: <http://www.mpifr-bonn.mpg.de/staff/mhatchell/>

Submillimeter CO emission from shock-heated gas in the L1157 outflow

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We present the CO $J=6-5$, $4-3$, and $3-2$ spectra from the blueshifted gas of the outflow driven by the low-mass class 0 protostar in the L1157 dark cloud. Strong submillimeter CO emission lines with $T_{\text{mb}} > 30$ K have been detected at $63''$ (~ 0.13 pc) south from the protostar. It is remarkable that the blue wings in the submillimeter lines are stronger by a factor of 3–4 than that of the CO $J=1-0$ emission line. The CO line ratios suggest that the blueshifted lobe of this outflow consists of moderately dense gas of $n(\text{H}_2) = (1\text{--}3) \times 10^4 \text{ cm}^{-3}$ heated to $T_{\text{kin}} = 50\text{--}170$ K. It is also suggested that the kinetic temperature of the outflowing gas increases from ~ 80 K near the protostar to ~ 170 K at the shocked region in the lobe center, toward which the largest velocity dispersion of the CO emission is observed. A remarkable correlation between the kinetic temperature and velocity dispersion of the CO emission along the lobe provides us with direct evidence that the molecular gas at the head of the jet-driven bow shock is indeed heated kinematically. The lower temperature of ~ 80 K measured at the other shocked region near the end of the lobe is explained if this shock is in a later evolutionary stage, in which the gas has been cooled mainly through radiation of the CO rotational lines.

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Dense gas and cold dust in the dark core B217

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The Barnard object B217 was observed in the infrared and radio region. The 170 μm continuum was detected with ISOPHOT, the ammonia 1.3 cm radio lines with the Effelsberg 100 m-telescope. Mapping B217SW in $(J, K) = (1, 1)$ and $(2, 2)$ inversion lines revealed the temperature and density distribution of the gas and made it possible to investigate the dynamical state of this dense core inside B217. The ISOPHOT Serendipity Survey (ISOSS) detected the cold dust emission of B217 in all of 3 slews crossing the region. Combining ISOSS with IRAS data, we derive the core parameters of the dust from FIR emission and compare them with the NH_3 data, which sample the densest region of the core. This study shows the power of combining ISOSS 170 μm with IRAS/HIRES data in order to study the dust characteristics in nearby star forming regions on small spatial scales.

The (170 μm /100 μm) dust colour temperature is 11 K–12 K in the dense cores and 12 K–14 K in the other regions of B217. The low dust temperatures cannot be explained by attenuation of the interstellar radiation field alone and may reflect a change in the optical properties of the dust as compared to diffuse clouds. In B217SW, molecular depletion through freeze-out onto grains is suggested by the comparison of our FIR and NH_3 data with previous C^{18}O observations. On the basis of our ammonia data investigation, we find in B217SW dense gas with kinetic temperatures between 9 K and 12 K, increasing outwards. Using near-infrared extinction and NH_3 collisional excitation calculations, the fractional ammonia abundance ($N(\text{NH}_3)/N(\text{H}_2)$) is found to be $3\text{--}5\cdot 10^{-8}$, and the comparison of gas and dust observations supports this range. Knowing the ammonia abundance, we calculate the thermal, turbulent and gravitational energies of the dense core, which appears to be close to hydrostatic equilibrium. Our results are compatible with B217SW being now on the verge of collapse or in an early collapse phase.

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K' Band Polarimetric Imaging of S187 IR and S233

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K' band polarimetric images of star forming regions S187 IR and S233 are presented. In S187 IR, a bipolar near infrared nebula is observed around IRAS 01202+6133, with the southern part being bright and knotty, and the northern one faint and filamentary. The polarization pattern shows that the nebula is illuminated by a single near infrared source, which is associated with IRAS 01202+6133. A polarization disk is found around this source with the disk plane roughly perpendicular to the axis of the bipolar nebula. We conclude that this source is the driving source of the outflow in the region.

Two nebulae are detected in the S233 region. Associated with a compact infrared cluster, S233 A is roughly round in shape and shows a weak polarization pattern. The S233 B nebula shows roughly elongated geometry in the E-W direction. The polarization vectors divide it into three parts. Each part has distinctly different polarization from the others. The NE part of S233 B exhibits a centro-symmetric polarization pattern around a centroid, where we locate a deeply embedded source (DES), undetected in the K' band and shorter wavelengths. The DES is likely the exciting source of water masers and of the outflows in the S233 B region. The western part of the nebula shows a parallel polarization pattern but the SE part displays very little polarization.

Comparison of the morphology and polarization of the nebulae in different star forming regions suggests a close relationship between the evolutionary sequence of the YSOs and morphology of the associated nebulae.

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The T Tauri star RXJ 1608.6-3922 – not an eclipsing binary but a spotted single star

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High-resolution spectroscopy and photometric monitoring of the pre-main sequence star RXJ 1608.6-3922 shows that it is not an eclipsing binary, as previously claimed. Radial velocity measurements covering suitable time spans in order to detect a spectroscopic binary with the claimed period of about 7 days have been performed. The scatter of the radial velocity does not exceed 2.4 km s^{-1} , defining an upper mass limit of $24 M_{\text{Jupiter}}$ for any eclipsing companion orbiting this star with the claimed period. Photometric observations of RXJ 1608.6-3922 in 7 consecutive nights (i.e. as long as the claimed orbital period) reveal brightness variations of the order of 0.2 mag with a period of 3.6 days. The shape of the detected light curve differs from a light curve of the star recorded in 1996. The small variations of the radial velocity, the variable shape of the light curve, as well as (B-V) color variations suggest that the flux of RXJ 1608.6-3922 is modulated by spots on the stellar surface with a rotational period of 3.6 days. The stellar activity of this star seems to be highly variable, taking into account the variable shape of the light curve, with an amplitude varying from 0.5 to 0.2 mag in a few years, as well as hints for a variable H_{α} equivalent width.

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For preprints via ftp or WWW: <http://www.xray.mpe.mpg.de/~viki>

Large Area Mapping at 850 Microns. III. Analysis of the Clump Distribution in the Orion B Molecular Cloud

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We present results from a survey of a 900 arcmin^2 region of the Orion B molecular cloud, including NGC 2068, NGC 2071, and HH 24/25/26, at $850 \mu\text{m}$ using the Submillimeter Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope. Following the techniques developed by Johnstone *et al.* (2000a,b), we identify 75 independent objects and compute size, flux, and degree of central concentration. Comparison with isothermal, pressure-confined, self-gravitating Bonnor-Ebert spheres implies that the clumps have internal temperatures of 20 – 40 K and surface pressures $5.5 < \log P/k < 6.5$. The clump masses span $0.2 - 12.3 M_{\odot}$ assuming typical dust temperatures and a dust emissivity $\kappa_{850} = 0.01 \text{ cm}^2 \text{ g}^{-1}$. The distribution of clump masses is well characterized by a power-law $N(M) \propto M^{-\alpha}$ with $\alpha = 1.5 - 2.0$ for $M > 1.0 M_{\odot}$. Significant incompleteness makes determination of the slope at lower masses difficult. The two-point correlation function of the clump separations is measured revealing clustering on size scales $r < 1.5 \times 10^5 \text{ AU}$ with a radial power-law exponent $\gamma = 0.75$.

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Study of star formation in RCW 106 using far infrared observations

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High resolution far-infrared observations of a large area of the star forming complex RCW 106 obtained using the TIFR 1m balloon-borne telescope are presented. Intensity maps have been obtained simultaneously in two bands centred around 150 and 210 μm . Intensity maps have also been obtained at the four *IRAS* bands using HIRES processed *IRAS* data. From the 150 and 210 μm maps, reliable maps of dust temperature and optical depth have been generated. The star formation in this complex has occurred in five linear sub-clumps. Using the map at 210 μm , which has a spatial resolution superior to that of the *IRAS* at 100 μm , 23 sources have been identified. The spectral energy distribution (SED) and luminosity of these sources have been determined using the associations with the *IRAS* maps. Luminosity distribution of these sources has been obtained. Assuming these embedded sources to be ZAMS stars and using the mass-luminosity relation for these, the power law slope of the initial mass function is found to be -1.73 ± 0.5 . This index for this very young complex is about the same as that for more evolved complexes and clusters. Radiation transfer calculations in spherically symmetric geometry have been undertaken to fit the SEDs of 13 sources with fluxes in both the TIFR and the *IRAS* bands. From this, the r^{-2} density distribution in the envelopes is ruled out. Finally, a correlation is seen between the luminosity of embedded sources and the computed dust masses of the envelopes.

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The mean surface density of companions in a stellar-dynamical context

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Applying the mean surface density of companions, $\Sigma(r)$, to the dynamical evolution of star clusters is an interesting approach to quantifying structural changes in a cluster. It has the advantage that the entire density structure, ranging from the closest binary separations, over the core-halo structure through to the density distribution in moving groups that originate from clusters, can be analysed coherently as one function of the stellar separations r .

This contribution assesses the evolution of $\Sigma(r)$ for clusters with different initial densities and binary populations. The changes in the binary, cluster and halo branches as the clusters evolve are documented using direct N -body calculations, and are correlated with the cluster core and half-mass radius. The location of breaks in the slope of $\Sigma(r)$ and the possible occurrence of a binary gap can be used to infer dynamical cluster properties.

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The Formation of Stellar Clusters: Mass Spectra from Turbulent Molecular Cloud Fragmentation

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Star formation is intimately linked to the dynamical evolution of molecular clouds. Turbulent fragmentation determines where and when protostellar cores form, and how they contract and grow in mass via competitive accretion from the surrounding cloud material. This process is investigated, using numerical models of self-gravitating molecular cloud dynamics, where no turbulent support is included, where turbulence is allowed to decay freely, and where it is continuously replenished on large, intermediate and small scales, respectively. Molecular cloud regions without turbulent driving sources, or where turbulence is driven on large scales, exhibit rapid star formation in a clustered mode, whereas interstellar turbulence that carries most energy on small scales results in isolated star formation with low efficiency.

The clump mass spectrum of shock-generated density fluctuations in pure hydrodynamic, supersonic turbulence is not

well fit by a power law, and it is too steep at the high-mass end to be in agreement with the observational data. When gravity is included in the turbulence models, local collapse occurs, and the spectrum extends towards larger masses as clumps merge together, a power-law description $dN/dM \propto M^\nu$ becomes possible with slope $\nu \leq -2$. In the case of pure gravitational contraction, i.e. in regions without turbulent support, the clump mass spectrum is shallower with $\nu \approx -3/2$.

The mass spectrum of protostellar cores in regions without turbulent support and where turbulence is replenished on large-scales, however, is well described by a log-normal or by multiple power laws, similar to the stellar IMF at low and intermediate masses. The model clusters are not massive enough to allow for comparison with the high-mass part of the IMF. In the case of small-scale turbulence, the core mass spectrum is too flat compared to the IMF for all masses.

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A low-resolution preprint is available at astro-ph/0104127, in full-resolution at <http://www.ucolick.org/~ralf/Preprints/p13.abstract.html>.

V – (V-I) distance to Lupus 2

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We report a possible distance to the star forming cloud Lupus 2 of 360 pc, at least 150 pc larger than previously suggested. Despite the cloud’s small angular size and remoteness this distance estimate is corroborated by Hipparcos/Tycho data for field stars. The increased distance changes the mass estimate from 100 to $\sim 600 M_{\text{sun}}$ more like the masses for the other Lupus clouds, but more interestingly the virial ratio of the two C¹⁸O cores in Lupus 2 will be lowered by a factor of 2.4 making Lupus 2 more like Taurus than the remaining Lupus cores.

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A possible dependence of DF Tauri’s photometric activity on the relative orbital positions of the binary components

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We constructed a DF Tau historical lightcurve to analyze the character of stellar variability from 1900 to 2000. This time interval exceeds the orbital period $P \simeq 80$ yrs of the double system. At least two sections of enhanced photometric activity are present at the lightcurve, with the time interval between them being close to $P/2$. They correspond to the sections of the DF Tau companion orbit intermediate between apo- and periastron. A decreasing in stellar activity occurred near the last periastron epoch. We conclude that long-term variations of DF Tau activity are the result of modulation of primary circumstellar disc accretion rate by orbital motion of the companion. We predict that DF Tau activity will increase significantly in the near future.

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preprint available at <ftp://lnfm1.sai.msu.ru/pub/PEOPLE/lamzin>

Hydrodynamical Simulations of Jet- and Wind-driven Protostellar Outflows

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We present two-dimensional hydrodynamical simulations of both jet- and wind-driven models for protostellar outflows in order to make detailed comparisons to the kinematics of observed molecular outflows. The simulations are performed with the ZEUS-2D hydrodynamical code using a simplified equation of state, simplified cooling and no external heating, and no self-gravity.

In simulations of steady jets, swept-up ambient gas forms a thin shell that can be identified as a molecular outflow. We find a simple ballistic bow-shock model is able to reproduce the structure and transverse velocity of the shell. Position-velocity (PV) diagrams for the shell cut along the outflow axis show a convex spur structure with the highest velocity at the bow tip, and low-velocity red and blue components at any viewing angle. The power-law index of the mass-velocity relationship ranges from 1.5 to 3.5, depending strongly on the inclination. If the jet is time-variable, the PV diagrams show multiple convex spur structures and the power-law index becomes smaller than the steady jet simulation.

In simulations of isothermal steady wide-angle winds, swept-up ambient gas forms a thin shell which at *early* stages has a similar shape to the shell in the jet-driven model; it becomes broader at later times. We find the structure and kinematics of the shell is well described by a momentum-conserving model similar to that of Shu et al. (1991). In contrast to the results from jet simulations, the PV diagrams for the shell cut along the outflow axis show a lobe structure tilted with source inclination, with components that are primarily either red or blue unless the inclination is nearly in the plane of sky. The power-law index of the mass-velocity relationship ranges from 1.3 to 1.8. If the wind is time-variable, the PV diagrams also show multiple structures, and the power-law index becomes smaller than the steady wind simulation.

Comparing the different simulations with observations, we find that some outflows, e.g., HH 212, show features consistent with the jet-driven model, while others, e.g., VLA 05487, are consistent with the wind-driven model.

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The Bell Laboratories ^{13}CO Survey: Longitude-Velocity Maps

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A survey is presented of the Galactic plane in the $J = 1 - 0$ transition of ^{13}CO . About 73,000 spectra were obtained with the 7 m telescope at Bell Laboratories over a ten-year period. The coverage of survey is $(l, b) = (-5^\circ \text{ to } 117^\circ, -1^\circ \text{ to } +1^\circ)$, or 244 square degrees, with a grid spacing of $3'$ for $|b| < 0^\circ.5$, and a grid spacing of $6'$ for $|b| > 0^\circ.5$. The data presented here have been resampled onto a $3'$ grid. For 0.68 km s^{-1} channels, the rms noise level of the survey is 0.1 K on the T_R^* scale. The raw data have been transformed into FITS format, and all the reduction processes, such as correcting for emission in the reference positions, baseline removal and interpolation were conducted within IRAF using the FCRAO task package and additional programs. The reduced data are presented here in the form of longitude-velocity color maps at each latitude. These data allow identification and classification of molecular clouds with masses in excess of $\sim 10^3$ solar masses throughout the first quadrant of the Galaxy. Spiral structure is manifested by the locations of the largest and brightest molecular clouds.

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Ring Formation in Magnetically Subcritical Clouds and Multiple Star Formation

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We study numerically the ambipolar diffusion-driven evolution of non-rotating, magnetically subcritical, disk-like

molecular clouds, assuming axisymmetry. Previous similar studies have concentrated on the formation of single magnetically supercritical cores at the cloud center, which collapse to form isolated stars. We show that, for a cloud with many Jeans masses and a relatively flat mass distribution near the center, a magnetically supercritical ring is produced instead. The supercritical ring contains a mass well above the Jeans limit. It is expected to break up, through both gravitational and possibly magnetic interchange instabilities, into a number of supercritical dense cores, whose dynamic collapse may give rise to a burst of star formation. Non-axisymmetric calculations are needed to follow in detail the expected ring fragmentation into multiple cores and the subsequent core evolution. Implications of our results on multiple star formation in general and the northwestern cluster of protostars in the Serpens molecular cloud core in particular are discussed.

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New observations of the pulsating PMS star V351 Ori

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This is the abstract of your paper We present new precise photoelectric observations of the Pre–Main–Sequence δ Scuti star, V351 Ori. These new data show that V351 Ori pulsates in a mixture of several radial modes (at least four). The comparison between observations and detailed pulsational models allows us to provide independent constraints on the mass and luminosity of the star. The predicted distance is 210 pc, indicating that V351 Ori is much closer than the Orion star forming region. With an inferred mass of $1.8 M_{\odot}$ and an uncertain evolutionary stage, V351 Ori represents an excellent candidate for future asteroseismological studies that will assess whether it is a young PMS star (~ 6 Myr) or an evolved object (~ 1 Gyr) leaving the main-sequence.

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A Submillimeter Dust and Gas Study of the Orion B Molecular Cloud

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Using SCUBA on the JCMT, we obtained a map of $850 \mu\text{m}$ continuum emission from the Orion B molecular cloud. The map is $20' \times 40'$ in extent and covers much of the northern half of the GMC. 67 discrete continuum sources, or clumps, have been identified, many of which are grouped in three regions, near NGC 2071IR, NGC 2068, and HH 24/25/26. Masses of the sources range from 0.2 to $12 M_{\odot}$. About half of the area of our $850 \mu\text{m}$ map is covered by the current release of the 2MASS infrared survey. Of 40 clumps covered by the 2MASS, 14 have associated infrared sources detected in J, H, and K. Maps of ^{13}CO J=2–1 and C^{18}O J=2–1 line emission were obtained for two regions in order to find the gas column density. Formaldehyde spectra were obtained towards eight of the continuum clumps to determine the gas kinetic temperature. Three of the clumps with measured temperature are hot ($T_{kin} \geq 80$ K) while the other five are cold ($T_{kin} \leq 20$ K). The gas-to-dust ratios differ substantially between the two regions mapped in CO. In the NGC 2068 region we find close to constant ratios of dust to gas emission, except in one compact source. However in the HH 24/25/26 region the dust to gas emission ratio varies substantially with some of the brightest dust continuum sources almost absent in CO emission. One explanation is that CO molecules have frozen onto grains in the dense cores. Why this freeze-out should happen in the HH 24/25/26 cores but not in the NGC 2068 cores remains unexplained. A ^{12}CO J=3–2 map of the NGC 2068 region shows patches of high velocity gas associated with five of

the compact continuum sources. The presence of outflows provides strong evidence that the group of sources south of NGC 2068 is actively forming stars.

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A SCUBA survey of the NGC 2068/2071 protoclusters

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We report the results of a submillimeter dust continuum survey of the protoclusters NGC 2068 and NGC 2071 in Orion B carried out at 850 μm and 450 μm with SCUBA on JCMT. The mapped region is $\sim 32' \times 18'$ in size ($\sim 4 \text{ pc} \times 2 \text{ pc}$) and consists of filamentary dense cores which break up into small-scale ($\sim 5000 \text{ AU}$) fragments, including 70 starless condensations and 5 circumstellar envelopes/disks. The starless condensations, seen on the same spatial scales as protostellar envelopes, are likely to be gravitationally bound and pre-stellar in nature. Their mass spectrum, ranging from $\sim 0.3 M_{\odot}$ to $\sim 5 M_{\odot}$, is reminiscent of the stellar initial mass function (IMF). Their mass-size relation suggests that they originate from gravitationally-driven fragmentation. We thus argue that pre-collapse cloud fragmentation plays a major role in shaping the IMF.

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Preprint available at <http://www.submm.caltech.edu/~motte/papers.html#ngc2068> (965 Kb, PS-gzipped)
or <http://xxx.lanl.gov/abs/astro-ph/0105019>

Measurement and Interpretation of Deuterium Line Emission in the Orion Nebula

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We present new observations of the deuterium and hydrogen Balmer lines in the Orion Nebula. There is a real variation in the ratio of the deuterium to hydrogen line ratios across the nebula, being greatest in the emission from the largest proplyd (Orion 244-440). We also present the results of a detailed model for the emission of these lines, the hydrogen lines being the result of photoionization and recombination, while the deuterium lines are produced by fluorescent excitation of the upper energy states by the far-UV radiation from $\theta^1 \text{ Ori C}$. Comparison of the observations and predictions of the line intensities shows good agreement, both in the strength of the reference lines at $H\beta$ and also in the differences of the Balmer decrement for the two atoms. The fact that both the deuterium and hydrogen emission arise from mechanisms which count the near ultra-violet (deuterium) and photo-ionizing ultra-violet (hydrogen) photons from the dominant star means that there is little prospect of similar observations being useful for determination of D/H abundances in H II regions.

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Preprints can be obtained by anonymous ftp server at orion.phy.vanderbilt.edu within the directory `pub/outgoing/Deuterium` where it is the file `preprint.ps`.

A ballistic bow shock model for jet-driven protostellar outflow shells

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We analyze the dynamics of the shell produced when a bow shock from a collimated jet propagates into the surrounding medium. Under interstellar conditions, the shock is radiative, and a ballistic approximation for the shell flow is appropriate beyond the working surface where the jet impacts its surroundings. The solution is then determined by the ambient and jet densities and velocities and by the momentum impulse applied in the working surface. Using estimates for these impulses (confirmed by separate numerical simulations), we obtain solutions for the shell structure, and for the range of velocities in the shell at any point. We provide predictions for the position-velocity and mass-velocity relations expected for plane-of-sky bow-shock shells, and for the bulk shell properties. In a companion paper, we show that these analytic solutions are in excellent agreement with the results of direct numerical simulations. We argue that classical molecular (CO) outflows cannot be purely jet-driven, because the bow-shock shell solutions are much too elongated compared with observations. Finally, we suggest that the “spur” structures seen in position-velocity diagrams of observed molecular outflows are the manifestation of internal bow shocks which may be fit with our simple dynamical models.

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Gas phase production of NHD₂ in L134N

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We show analytically that large abundances of NH₂D and NHD₂ can be produced by gas phase chemistry in the interiors of cold dense clouds. The calculated fractionation ratios are in good agreement with the values that have been previously determined in L134N and suggest that triply-deuterated ammonia could be detectable in dark clouds. Grain surface reactions may lead to similar NH₂D and NHD₂ enhancements but, we argue, are unlikely to contribute to the deuteration observed in L134N.

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VLA Observations of Brightness Enhancements moving along the Axis of the Cep A HW2 Thermal Jet

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We analyze sensitive, high angular resolution (0'3) Very Large Array observations made at 6-cm of the thermal jet Cep A HW2 in two epochs separated by 1.3 years. The subtraction of the maps made at the two epochs clearly shows the presence of brightness enhancements that travel in the jet at a velocity of 950 ± 150 km s⁻¹. We also use these results to estimate an accurate position for the exciting star of this jet.

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The Tokyo-Onsala-ESO-Calán Galactic CO $J = 2 - 1$ Survey. I. The Galactic Center Region

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As a part of the Tokyo-Onsala-ESO-Calán Galactic CO survey, we have made large-scale mapping observations of the Galactic center in the CO $J = 2 - 1$ line using the 60 cm survey telescope in Chile. The data were taken with the same beam size ($9'$) and sampling grid ($7.5'$) as the CO $J = 1 - 0$ Columbia survey, so that the two datasets can be compared directly. Velocity channel maps and longitude-velocity diagrams of the $^{12}\text{CO } J = 2 - 1$ line covering $-6^\circ \leq \ell \leq +6^\circ$, $-2^\circ \leq b \leq +2^\circ$, $-300 \text{ km s}^{-1} \leq v_{\text{LSR}} \leq +300 \text{ km s}^{-1}$ are presented along with the corresponding maps of the $^{12}\text{CO } J = 2 - 1/J = 1 - 0$ intensity ratio ($R_{2-1/1-0}(^{12}\text{CO})$). A longitude-velocity diagram of the $^{13}\text{CO } J = 2 - 1$ line intensity and corresponding $^{13}\text{CO } J = 2 - 1/^{12}\text{CO } J = 2 - 1$ intensity ratio ($R_{13/12}(J = 2 - 1)$) are also presented at $b = 0^\circ$. The overall $R_{2-1/1-0}(^{12}\text{CO})$ in the central 900 pc of the Galaxy is 0.96 ± 0.01 , which is higher than the typical value in the Galactic disk, 0.6-0.7. The isotopic intensity ratio $R_{13/12}(J = 2 - 1)$ is 0.10 ± 0.01 . The observed two intensity ratios ($R_{2-1/1-0}(^{12}\text{CO})$ and $R_{13/12}(J = 2 - 1)$) indicate that the optical depth of the $^{12}\text{CO } J = 1 - 0$ line is ~ 1 or smaller in the Galactic center molecular clouds, much smaller than those of the giant molecular clouds (GMCs) in the Galactic disk. Longitude-velocity distributions of physical properties of molecular gas are derived using an LVG analysis. Molecular gas in the Galactic center generally shows a high pressure. Particularly, there is a high pressure region in the central ~ 100 pc where the pressure is an order of magnitude higher than that in GMCs in the Galactic disk. This region is dominated by high density gas and contains star forming regions.

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Comparative seismology of pre- and main sequence stars

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Pulsational properties of $1.8 M_\odot$ stellar models covering the latest stages of contraction toward the main sequence up to early hydrogen burning phases are investigated by means of linear nonadiabatic analyses. Results confirm that pre-main sequence stars (pms) which cross the classical instability strip on their way toward the main sequence are pulsationally unstable with respect to the classical opacity mechanisms. For both pms and main sequence types of models in the lower part of the instability strip, the unstable frequency range is found to be roughly the same. Some non-radial unstable modes are very sensitive to the deep internal structure of the star. It is shown that discrimination between pms and main sequence stages is possible using differences in their oscillation frequency distributions in the low frequency range.

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The Probability Distribution Function of Column Density in Molecular Clouds

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We discuss the probability distribution function (PDF) of column density resulting from density fields with lognormal PDFs, applicable to isothermal gas (e.g., probably molecular clouds). For magnetic and non-magnetic numerical simulations of compressible, isothermal turbulence forced at intermediate scales (1/4 of the box size), we find that the autocorrelation function (ACF) of the density field decays over relatively short distances compared to the simulation size. We suggest that a “decorrelation length” can be defined as the distance over which the density ACF has decayed to, for example, 10% of its zero-lag value, so that the density “events” along a line of sight can be assumed to be independent over distances larger than this, and the Central Limit Theorem should be applicable. However, using random realizations of lognormal fields, we show that the convergence to a Gaussian is extremely slow in the high-density tail. As a consequence, the column density PDF is not expected to exhibit a unique functional shape, but to transit instead from a lognormal to a Gaussian form as the ratio η of the column length to the decorrelation length (i.e., the number of independent events in the cloud) increases. Simultaneously, the PDF’s variance decreases. For intermediate values of η , the column density PDF assumes a nearly exponential decay. For cases with a density contrast of 10^4 (resp. 10^6), as found in intermediate-resolution simulations, and expected from GMCs to dense molecular cores, the required value of η for convergence to a Gaussian is at least a few hundred (resp. several thousand). We then discuss the density power spectrum and the expected value of η in actual molecular clouds, concluding that they are uncertain since they may depend on several physical parameters.

Observationally, our results suggest that η may be inferred from the shape and width of the column density PDF in optically-thin-line or extinction studies. Our results should also hold for gas with finite-extent power-law underlying density PDFs, which should be characteristic of the diffuse, non-isothermal neutral medium (temperatures ranging from a few hundred to a few thousand degrees). Finally, we note that for $\eta \geq 100$, the dynamic range in column density is small (\leq a factor of 10), but this is only an averaging effect, with no implication on the dynamic range of the underlying density distribution.

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Submillimeter CO Line Emission from Orion

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Images of an 8 square minute region around the Orion KL source have been made in the $J = 7 - 6$ (806 GHz) and $J = 4 - 3$ (461 GHz) lines of CO with angular resolutions of $13''$ and $18''$. These data were taken employing on-the-fly mapping and position switching techniques. Our $J = 7 - 6$ data set is the largest image of Orion with the highest sensitivity and resolution obtained so far in this line. Most of the extended emission arises from a Photon Dominated Region (PDR), but 8% is associated with the Orion ridge. For the prominent Orion KL outflow, we produced ratios of the integrated intensities of our $J = 7 - 6$ and $4 - 3$ data to the $J = 2 - 1$ line of CO. Large Velocity Gradient (LVG) models fit the outflow ratios better than PDR models. The LVG models give H_2 densities of $\sim 10^5 \text{ cm}^{-3}$. The CO outflow is probably heated by shocks. The data for Orion S suggest that this source is located *inside* the HII region, near the rear of Orion A. In the Orion S outflow, the CO line intensities are lower than for Orion KL. The $4 - 3/2 - 1$ line ratio is 1.3 for the blue shifted wing and 0.8 for the red shifted wing. Emission in the jet feature extending $2'$ to the SW of Orion S was detected in the $J = 4 - 3$ but not the $J = 7 - 6$ line; the average $4 - 3/2 - 1$ line ratio is ~ 1 . Comparisons of the intensities of the $J = 7 - 6$ and $J = 4 - 3$ lines from the Orion Bar with PDR models show that the ratios exceed predictions by a factor of 2. Either clumping or additional heating by mechanisms, such as shocks,

may be the cause of this discrepancy.

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The formation of heavy hydrocarbons in molecular clouds

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Laboratory data on the conversion of solid methane into large hydrocarbons by particle radiation are used to estimate the fraction of interstellar carbon converted by this process into refractory form. We find that the maximum fraction of carbon that can be converted into refractory form during the life of a dense core within an interstellar cloud is in the range of 1 - 5 percent. The implication of this result is that the conversion of enough carbon into refractory form to contribute significantly to interstellar extinction requires the frequent passage of material into and out of dense cores. If so, then interstellar clouds must exist for at least 10 My. However, these conclusions should be regarded as preliminary until confirmed by further laboratory studies of the particle irradiation of complex ice mixtures.

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A Subarcsecond Radio Binary Associated with AFGL 4029-IRS1

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We present sensitive, high angular resolution ($0''.3$) Very Large Array observations made at 3.6-cm of the bright infrared source AFGL 4029. We find that the radio source G138.295+1.555, associated with AFGL 4029-IRS1, is actually a subarcsecond binary separated by $0''.6$ approximately in the north-south direction. There is also fainter emission extending in the east-west direction and emanating from G138.295+1.555(S), the southern component of the binary. We then identify G138.295+1.555(S) as the exciting source of the optical and molecular outflow observed in this region. G138.295+1.555(S) appears to be one of the few massive young stars associated with a collimated outflow. The northern component of the binary, G138.295+1.555(N), appears to exhibit time-variable radio emission and is proposed to be associated with a T Tauri star. The source G138.300+1.558, associated with AFGL 4029-IRS2, is an ultracompact H II region of cometary morphology, possibly ionized by a B1 ZAMS star.

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

Search for CO Outflows toward a Sample of 69 High-Mass Protostellar Candidates: Frequency of Occurrence

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A survey for molecular outflows was carried out by mapping the CO J=2-1 line toward a sample of 69 luminous IRAS point sources. 60 objects have IRAS luminosities from 10^3 to $10^5 L_{\odot}$ and are associated with dense gas traced by

NH₃, identifying them as high-mass star forming regions. Among 69 sources, 65 sources have data that are suitable for outflow identification. 39 regions show spatially confined high velocity wing emission in CO, indicative of molecular outflows. Most objects without identifiable outflows lie within $0 < l < 50^\circ$ where outflow signatures are confused by multiple cloud components along the line of sight. Excluding 26 sources with $0 < l < 50^\circ$, we found 35 outflows out of 39 sources, which yields an outflow detection rate of 90%.

Many of the outflows contain masses of more than $10 M_\odot$ and have momenta of a few hundred $M_\odot \text{ km s}^{-1}$, at least two orders of magnitude larger than those in typical low-mass outflows. This class of massive and energetic outflows are most likely driven by high-mass young stellar objects. The high detection rate indicates that molecular outflows are common toward high-mass young stars. Given the connection between outflows and accretion disks in low-mass stars, we suggest that high-mass stars may form via an accretion-outflow process, similar to their low-mass counterparts.

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Preprint: <http://cfa-www.harvard.edu/~qzhang> or <http://cfa-www.harvard.edu/sfgroup>

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Dissertation Abstracts
Physical Properties of Protostars

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Prominent star forming regions have been investigated at wavelengths between $1.2\mu\text{m}$ to $1300\mu\text{m}$, covering a large mass spectrum of the observed young stellar objects. Their evolutionary stages were determined by established classification procedures and turned out to range from collapsing cloud fragments, Class 0 protostars to more evolved Class I sources. The creation of spectral energy distributions allowed to derive physical properties like temperatures, luminosities, masses and densities by fitting modified Planck functions to the measured flux distributions. For source extents that exceed the expected size of a pointsource, their dimensions have been obtained by two-dimensional Gaussian fits. In cases, where measurements from different epochs exist, a possible temporal evolution has been discussed.

The study of low-mass objects has been carried out in dark molecular clouds, widely spread throughout the galactical plane, where Herbig–Haro objects are a signpost of star formation activity. 7 of 17 observed sources are Class 0 protostars, with HH 108 MMS being one of the youngest stellar objects discovered so far. 5 additional objects appear to be in a transitional stage between Class 0 and Class I. A surprising result of this study was the detection of Herbig–Haro objects at (sub)millimetre wavelengths which could originate from warm dust, compressed by the associated molecular outflows or jets.

The bright emission nebula M 17 (Omega nebula, NGC 6618) has been chosen as a template for high-mass star formation, where the investigations were concentrated on the adjacent molecular cloud M 17 SW. In order to examine the warm extended dust, mid-infrared maps, created from 133 single images at $10.5\mu\text{m}$ and $20.0\mu\text{m}$ covering ~ 17 sqmin, have been produced. An eye-catching dust ridge of $4'.5$ length and a colour temperature of 230 K has been found which most probably consists of dense dust, swept up by an advancing ionization front. The mosaic shows 22 compact sources which have been investigated in more detail; 4 are new detections. All sources satisfy the Class I criterion; 4 of them lie close to the Class II borderline. The observed objects comprise a binary of massive young stars, one of those being a quickly evolving ultra-compact H II region, massive Class I sources surrounded by dust cocoons and circumstellar disks, and probably the first detection of a protostellar spiral.

<http://www.astro.ruhr-uni-bochum.de/nielbock/promotion/>