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Abstracts of recently accepted papers

The formation of close binary systems

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A viable solution to the origin of close binary systems, unaccounted for in recent theories, is presented. Fragmentation, occurring at the end of the secondary collapse phase (during which molecular hydrogen is dissociating), can form binary systems with separations less than 1 au.

Two fragmentation modes are found to occur after the collapse is halted. The first consists of the fragmentation of a protostellar disc due to rotational instabilities in a protostellar core, involving both an $m = 1$ and an $m = 2$ mode. This fragmentation mechanism is found to be insensitive to the initial density distribution: it can occur in both centrally condensed and uniform initial conditions. The second fragmentation mode involves the formation of a rapidly rotating core at the end of the collapse phase which is unstable to the axisymmetric perturbations. This core bounces into a ring which quickly fragments into several components.

The binary systems thus formed contain less than 1 per cent of a solar mass and therefore will need to accrete most of their final mass if they are to form a binary star system. Their orbital properties will thus be determined by the properties of the accreted matter.

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Deep VLA search for the youngest protostars: A Class 0 source in the HH24–26 region

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As part of a comprehensive centimeter radio continuum survey of molecular cloud cores for deeply embedded young stellar objects, we present deep 3.6 cm VLA observations of the HH24-26 region in the L1630 Orion molecular complex. Above a 5 σ sensitivity threshold of 0.1 mJy, six radio sources are detected whose spatial distribution closely follows that of the dense molecular gas in the region. In addition to the previously known infrared objects SSV61 and SSV63, our observations reveal two new, weak VLA sources which coincide with strong HCO^+ and dust continuum peaks. One of them is the protostellar cold cloud fragment HH24MMS recently discovered at 1.3 mm by Chini et al. Based on the detection of this object with the VLA, we argue that HH24MMS is a Class 0 young protostar rather similar to, but probably more massive than, the ρ Ophiuchi Class 0 source VLA 1623.

Accepted by A&A

The Growth of Solids and Radiation Shielding in the Young Stellar Disk of HD 45677

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Ultraviolet spectra (912-3300 Å) from the ASTRO-1 and IUE space missions of two Herbig Be stars, HD 45677 and HD 200775, show that the HD 200775 intrinsic continuum matches a T=20,000 K Kurucz model and that the HD 45677 continuum exhibits additional line-blanketing, extinction, and emission from gas and dust in its disk and bipolar wind. With log N(H I)=21.4±0.1 cm^{-2}, our measured upper limit on the fraction of HD 45677 disk H-atoms in molecules (f¡1.5x10^{-2}) is much less than that seen in molecular clouds (f≈0.5). The HD 45677 dust absorption for λ>1400 Å(A_V≈0.7 mag) is produced by larger grains (inferred R_V≈6.2) than those in molecular clouds (R_V¡5.6). A steep FUV absorption (1300- 1000 Å) toward HD 45677 is partly due to an excess of hydrocarbon molecules that barely shield (τ ≈1-2.5) the outer disk from FUV radiation. Both the disk gas and dust have evolved greatly since the formation of the mid-mass star HD 45677 from molecular clouds: the disk grains grew to micron sizes suitable fro the formation of planetesimals, the molecular hydrocarbons photoevaporated off grains in the gaseous disk, and the ISM H_2 photodissociated into HI in the disk. Thus, because of radiation from HD 45677, the disk gas differs dramatically from the condensate-rich, molecular gas around low-mass stars and would seam to lead to a different chemical and physical evolution toward planets than around low-mass stars such as our Sun.

A Search for Pre-Main Sequence Stars in High-Latitude Molecular Clouds. III. A Survey of the *Einstein* Database

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In order to discern whether the high-latitude molecular clouds are regions of ongoing star formation, we have used X-ray emission as a tracer of youthful stars. The entire *Einstein* database yields 18 images which overlap 10 of the clouds mapped partially or completely in the CO (1-0) transition, providing a total of ∼ 6 sq. deg. of overlap. Five previously unidentified X-ray sources were detected: one has an optical counterpart which is a pre-main-sequence star and two have normal main sequence stellar counterparts, while the other two are probably extragalactic sources. The PMS star is located in a high Galactic latitude Lynds dark cloud, so this result is not too surprising. The translucent clouds, though, have yet to reveal any evidence of star formation.

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A massive young embedded object associated with the UC HII region G31.41+0.31

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We have used the IRAM Plateau de Bure Interferometer to make high angular resolution observations of the star-forming region surrounding the ultracompact HII region G31.41+0.31. We have produced maps in the ground state CH_3CN(6–5), $CH_3{}^{13}CN$(6–5) and vibrationally excited CH_3CN(6–5) transitions, and in the 3 mm continuum emission. From these, we derive estimates of the size and mass of the hot molecular core known from earlier ammonia observations. The core angular diameter as measured in both methyl cyanide and the 3 mm continuum is $\sim 1'$ corresponding to ∼ 0.04 pc. If the continuum emission is due to heated dust, we derive a mass of $\sim 1000\ M_\odot$, but with large uncertainties. A remarkable velocity gradient ($\sim$ 400 km s^{-1} pc^{-1}) in the SW–NE direction is observed in CH_3CN implying an equilibrium mass $\sim 1000\ M_\odot$, consistent with the value quoted above. We discuss two possible scenarios (disk or outflow) for explaining this gradient and conclude that the molecular core must be dynamically unstable.

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Near-infrared imaging of the jets and flows associated with the Herbig-Haro objects 91, 110 and 111.

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We present near-infrared imaging of the jets and outflows associated with the Herbig-Haro (HH) objects HH 91, HH 110 and HH 111. We compare our narrow-band H_2 v=1-0 S(1) (2.121 μm) and broad band K images with optical [SII] and Hα images of the same regions. We find that many of the brightest knots in [SII] and Hα have counterparts in H_2, though there are some marked differences in morphology. In HH 91, the H_2 emission is highly clumpy, like the [SII] emission, though the H_2 is mostly confined to the low-excitation regions of the flow. H_2 emission also coincides with and outlines the northern edge of a filamentary, optical, "jet-like" feature in HH 91. We interpret this as possible evidence for entrainment of ambient gas along the northern boundary of this flow. More striking differences between the H_2 and optical data are seen in the HH 110 outflow. The "wiggling" Hα jet appears much straighter in H_2. We suggest that close to the source the H_2 traces a laminar, mostly molecular jet, while the Hα traces a more extensive turbulent "mixing layer" that separates the jet from the ambient medium. Also, near to HH 110 we have found a second and probable third collimated H_2 jet. Neither jet is visible in optical images of the region. Finally, in HH 111 we see the brightest optical features also in H_2, including the bow shock at the westerly head of the jet, knot V. Along the jet, the H_2 peaks coincide closely with the [SII] knots (after taking into account proper motions), though in knot V, the H_2 is shifted upstream of the [SII] peak by $\sim$ 1 arcsec (400 AU): the H_2 therefore probably derives from the bow shock wings in knot V.

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Modeling Radiative Transfer in Molecular Clouds I. HCO^+ in the Star-Forming Region W49 A North.

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A new general multi-level, non-LTE radiative transfer code, valid for any velocity field, is applied to HCO^+ observations of W49 A north. Three classes of collapse models are considered: free-fall collapse (v $\propto$ $r^{-0.5}$), homologous collapse (v $\propto$ r), and "inside-out" collapse (Shu 1977). A simple free-fall collapse model, with $\rho \propto r^{-1.5}$ throughout the molecular cloud, successfully reproduces the features of the observations and gives the best fit to the J=1-0 and J=3-2 profiles both toward the prominent HII component G of W49 A north and off the center. In addition to a slow radial fall-off of density, the theoretical modeling implies for the molecular cloud: the large line widths result from motions occurring within the inner 1 pc and there are probably one or more fragments with peculiar velocities within this same region.

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On the Current Status of Maser Polarization Theory

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Despite recent criticism, past conflicts among theoretical studies of maser polarization are by now resolved and clarified. All analytical methods proposed thus far produce the same polarization solutions, solutions that agree with observations. Current numerical studies do not reproduce these solutions. Instead, for any pumping employed, their results are in direct conflict with both analytical theory and observations. These problems reflect the fact that the

basic formulation of numerical modeling has yet to incorporate the statistical nature of the radiation field.

(A preprint of this paper may be found through **http://www.pa.uky.edu/** the Mosaic home page of the Department of Physics and Astronomy.)

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When Star Formation Stops: Galaxy Edges and Low Surface Brightness Disks

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The star formation rate per unit gas mass should be low wherever the average gas pressure is low because most compressions in these regions, whether from old supernova shocks, gravitational instabilities, cloud collisions, supersonic turbulence, or spiral waves, cannot produce gas that is dense enough to cool to low thermal temperatures. All of the normal routes to star formation shut off when the average pressure is much less than the minimum critical pressure for the co-existence of two thermal phases. We calculate this minimum critical pressure $P_{\rm min}$ and the corresponding densities for gas in thermal equilibrium for a variety of radiation fields, metallicities, and cosmic ray fluxes. Low total pressure usually correlates with low gas surface density in a galaxy, so if the thermal pressure, which is only part of this total, decreases as the total pressure decreases, then the low surface density regions that are at large radii in normal galaxies or in low surface brightness galaxies should have sufficiently low thermal pressures to prevent star formation in all but the highest-pressure fluctuations. Star formation stops because without the possibility of low equilibrium temperatures, no amount of cooling, and no likely amount compression subsequent to cloud formation (as in turbulence) can produce clump masses that exceed the thermal Jeans mass. We predict that HI in the outer parts of galaxies and in regions with low ratios of pressure to radiation field should have most of their mass at temperatures in excess of several thousand Kelvin, and very little of their mass in a dense form appropriate for star formation.

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Millimeter and submillimeter observations of the Orion Bar. I–Physical structure

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Millimeter and submillimeter observations of 53 rotational transitions of 18 different molecules and their isotopic varieties are presented at five positions on a strip crossing the Orion Bar. These data are used to study the physical and chemical conditions with increasing depth into this photon–dominated region (PDR). It is found that all molecules show about the same intensity distribution across the Bar. They peak $\sim 30''$ outside the ionization front, and fall off to about 10–20% of their peak values on either side. An excitation analysis of $C^{18}O$, H_2CO, CS and HCO^+ shows that the Orion Bar is best described by an inhomogeneous density distribution where $\sim 10\%$ of the molecular material is comprised in clumps of hydrogen number density $n_{\rm H_2} \approx 1^{+3.0}_{-0.7}\,10^6$ cm^{-3} and $\sim 90\%$ in a homogeneous interclump medium of $n_{\rm H_2} \approx 3^{+2.0}_{-2.2}\,10^4$ cm^{-3}. The kinetic temperature is found to be 85 ± 30 K. No significant variations in these physical parameters occur across the Bar. It is therefore concluded that the observed peak in the molecular rotational emission corresponds to a peak in molecular column densities. A geometric model for the Orion Bar is proposed in which with increasing distance from the ionizing stars, the PDR changes from a face–on to an edge–on geometry and back. The increased emission is then caused by the increased length of the line–of–sight through the PDR. This model is found to correspond well with other observations.

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X-ray-selected T Tauri stars in the Chamaeleon I cloud

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We report spectroscopy of 26 stars associated with 23 fields containing proposed new X-ray-selected cloud members of Chamaeleon I. At least 13, and possibly as many as 19, of the stars are confirmed to be new 'weak-lined' T Tauri (WTT) stars due to the presence of Hα emission and strong λ6707 Li I absorption. Of the remainder, we suspect that five of the observed stars are not the X-ray emitters. Only two X-ray-emitting stars are found to be unrelated to the cloud. The available evidence suggests that the WTT stars are not systematically older than 'classical' T Tauri (CTT) stars in Chamaeleon. The transition between CTT and WTT stages for individual stars must range over most of the Hayashi track.

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Theoretical Position-Velocity Diagrams of Flux, Electron Density, and Electron Temperature in Herbig-Haro Objects

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Many features of Herbig-Haro objects can be reproduced using a kinematical bow shock model. We use the model to generate position-velocity (PV) diagrams of flux in H_α, [O I]$\lambda\lambda$6300+63, [S II]$\lambda\lambda$6716+31, [O III]$\lambda\lambda$4959+5007, and [C I]$\lambda\lambda$9823+50, line ratios of [O I]/Hα, [O I]/[S II], [S II]/Hα, Hα/[S II], and [O III]/Hα, electron density N_e, and temperature T_e. We show how PV diagrams of N_e and flux vary with shock velocity. By matching the diagrams from single lines, line ratios and N_e with observations, we determined a narrow range of shock parameters for HH 1F, 2(A′+H), and 43(B+C). We model the N_e features of HH 2(A′+H) as a superposition of 2 bowshocks. We also show that the effects of slight misalignments of the two diagrams to be divided can produce artifacts in line ratios and N_e, which obliterate the physical features. We show that N_e in HH 1 can only be explained using the kinematical model by taking these misalignments in to account.

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Composite Spectra in Young Stars: Accretion or Close Companions?

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Three young low-mass stars which exhibit composite optical spectra were imaged at high angular resolution in the near-infrared to determine whether their spectral peculiarities are due to the presence of close binary companions. Companions to two of the three stars were found to be capable of producing the observed spectra, but only if they are much younger than their primaries. If the inferred age differences are real, they suggest that a mechanism must exist which can perturb the evolution of a young star in a binary system from its Hayashi track.

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Protostellar Accretion Disks Resolved with the JCMT–CSO Interferometer

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The JCMT–CSO submillimeter interferometer was used to measure the size and orientation of the compact dust continuum emission at 870 μm from the protostellar sources HL Tau and L1551–IRS 5. Assuming an elliptical Gaussian for the brightness distribution and distances of 140 pc, the data are well fit by semi-major radii to half maximum brightness and position angles of 60 AU at 126 degrees for HL Tau and 80 AU at 162 degrees for L1551. An upper limit of 50 AU ($0.''4$) is set for the radii along the minor axes, leading to minimum brightness temperatures of 36 K and 28 K, respectively. The elongation in the continuum emission is perpendicular to the outflow axes, as expected for accretion disks. The high brightness indicates substantial column density and mass, further strengthening the accretion disk interpretation. Our observations do not strongly constrain the disk mass; applying an accretion disk model to our data gives a lower limit of $\sim$0.02 $M_\odot$ for both sources.

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The CI/CO ratio in the molecular cloud G34.3+0.2

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A model for the structure of the massive molecular cloud G34.3+0.2 is derived from extensive observations of carbon monoxide lines including J=1–0, 2–1, 3–2 and 6–5 ^{13}CO and J=2–1 C^{18}O. The model consists of a slowly collapsing turbulent cloud with density constant out to a radius of 0.15pc, but falling off as $\sim R^{-2}$ out to 3.25pc. The CO abundance is constant. Within the framework of the basic cloud structure it is possible to predict line shapes for the 492GHz $^3P_1$–$^3P_0$ CI line, for different assumed radial behaviour of the CI abundance. These are compared with observations. The best fit is found with CI $\propto R^{0.9}$ from the perimeter of the cloud into r =0.24pc where A_V=55. The column density averaged [CI]/[CO] ratio for G34.3+0.2 is very similar to that for the ρ Ophiuchus molecular cloud notwithstanding the very different structures of the two clouds. Models for producing high carbon abundances deep in clouds which may have difficulty in explaining the results include those with external UV penetration round clumps, dynamic mixing or in which the initial [C]/[O] ratio is greater than unity.

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Millimeter-wave Continuum Measurements of Young Stars

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New continuum observations at 1.3 mm of 121 young stars are presented; the majority of these objects have not been previously observed. The stars which are detected are interpreted assuming that the emission is thermal radiation from small particles entrained in circumstellar disks. Several new conclusions are drawn:

1. The presence of a companion star clearly affects the millimeter-wave continuum emission and, by implication, the disks. Companions closer than about 100 AU inhibit disk formation.

2. Weak-line and naked T Tauri stars do, in fact, have less millimeter-wave emission than classical T Tauri stars. It appears that the reason is an absence of even cold particles, not simply lower luminosites for an otherwise large reservoir of particles. An equivalent width for H_α of 0.4 nm appears to be a natural dividing line between detected and non-detected sources.

3. Within the uncertainties, there is no difference between the distribution of disk masses in the Cepheus IV association and Taurus-Auriga.

4. With better sensitivity, the distribution of disk masses can be seen to extend down below the approximate limit of 0.01 solar masses determined in the survey of Beckwith et al. (1990).

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$H^{13}CN$, $H^{13}CO^+$, HCN and HCO^+ observations of dense gas in galactic molecular clouds

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The results of the observations of several galactic dense molecular cloud cores in the $J = 1-0$ $H^{13}CN$, $H^{13}CO^+$, HCN and HCO^+ lines along with the $J = 1-0$ HCN observations of some high-latitude clouds are presented. In the optically thin approximation the $H^{13}CN$ and $H^{13}CO^+$ column densities (N) are evaluated. HCN and HCO^+ column densities are derived from $N(H^{13}CN)$ and $N(H^{13}CO^+)$ using the $[^{12}C]/[^{13}C]$ ratios for each cloud calculated from its galactocentric dependence. HCN abundances are found for two objects. The $H^{13}CO^+$, HCO^+ and HCN emission region sizes are estimated for some cores. HCO^+ and $H^{13}CO^+$ model calculations for S140 show that either the $[HCO^+]/[H^{13}CO^+]$ abundance ratio is rather low, ~ 30, or the object has inhomogeneous structure. The $J = 1-0$ HCN line was detected towards MBM 55B high-latitude cloud. HCN column density in this source is $N(\mathrm{HCN}) \geq 9 \cdot 10^{11}$ cm^{-2}, the HCN abundance is $X(\mathrm{HCN}) > 10^{-10}$.

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Proto–Brown Dwarfs II. Results in the Ophiuchus and Taurus Molecular Clouds

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We expand our proto–brown dwarf search to include two nearby star-forming regions in the Ophiuchus and Taurus molecular clouds. In both molecular line and continuum searches in the Ophiuchus B and Barnard 18 (in Taurus) star-forming regions, we find no clear-cut evidence of *any* proto–brown dwarfs. This lack of proto–brown dwarfs is surprising; even if the IMF (given by $dN/dM \propto M^{-\alpha}$) were flat ($\alpha = 1$), we would expect to have found ~ 10 objects. We do find, however, a few candididate objects near our detection limit (~ 0.02 $M_\odot$) which deserve further scrutiny.

We find 21 gravitationally bound clumps distributed in mass with a spectral index $\alpha = 1.1 \pm 0.2$. However, there are fewer low-mass clumps ($\lesssim 0.1$ $M_\odot$) than would be expected from extrapolation of any reasonable mass function, including the well-known giant molecular cloud clump mass spectrum. If the IMF follows the clump mass spectrum below 0.08 $M_\odot$, as it does at higher masses, our results in Oph B imply that, unless some undetermined process causes the production of many more low-mass clumps, the IMF is *falling* at masses below 0.08 $M_\odot$, *even if all our candidate objects turn out to be true proto–brown dwarfs.* We therefore predict that future searches for brown dwarfs will find very few, regardless of the depth of the searches.

The measured clump spectrum is evidence that there is a mass range (0.1 to 0.25 $M_\odot$) where the molecular cloud clump mass spectrum has the same slope stellar initial mass function ($\alpha \sim 1$). This is an indication that there is indeed a direct relationship between clump mass and subsequent stellar mass at the scale of a few tenths of a solar mass.

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Dense Gas in High-Latitude Molecular Clouds

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The nearby molecular clouds MBM 7, 12, 30, 32, 40, 41, and 55 were surveyed for tracers of dense gas, including the (1–0), (2–1), and (3–2) rotational lines of CS and the (1–0) lines of HCO^+ and HCN. MBM 7 and MBM 12 contain dense cores, while the other clouds contain little or no traces of dense gas. Comparison of the emission from dense gas tracers to that of ^{13}CO reveals that the former are more compact in angular size as well as linewidth. An extensive CS(2–1) survey of part of MBM 12 reveals that the emission is characterized by clumps on $\sim 3'$ scales as well as extended emission. Observations of the CS(1–0) and (3–2) lines using telescopes with matched beamsizes reveal that the volume density must be at least $\sim 10^{4.5}$ cm^{-3} within the (3–2) emitting regions, which are ~ 0.03 pc in radius. Electron-excitation of the CS rotational levels is ruled out (in the cores) by comparing the (3–2)/(1–0) line ratios with models including H_2 and electron collisions. The volume density in the cores is substantially larger than in the portions of the cloud traced by CO emission. The density increases into the cores as r^{-2}, suggesting dynamical collapse. The masses of the cores are close to the virial mass, suggesting they are dynamically bound. The cores in MBM 7 and MBM 12 are thus likely to form stars, and represent the nearest sites of star formation.

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The Distribution of Molecular and Neutral Gas and Magnetic Fields Near the Bipolar HII Region S106

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VLA Zeeman observations of absorption lines of neutral hydrogen (HI) and the hydroxyl radical (OH) have been carried out toward the bipolar outflow HII region S106 at a resolution of $\sim 20''$ with an rms noise of ~ 3 mJy beam^{-1}. The results of the observations are interpreted in terms of a model for the absorption line gas in which some of the OH and HI gas has been accelerated by the passage of a shock front and some of the gas lies outside the shock front at the undisturbed velocity of the molecular cloud.

Two distinct OH absorption features are due to gas associated with S106. One component, which is identified with the unshocked gas, is narrow ($\Delta v_{\rm FWHM}$ = 1.2 to 2.9 km s^{-1}) and is observed at small negative velocities ($v_{\rm LSR}$ = –2.4 to –1.0 km s^{-1}). This component shows a large peak in opacity at the eastern edge of the HII region near a previously observed molecular cloud core; the H_2 mass of this component is estimated to be $\sim 13\ M_\odot$. Additionally, there is a wide ($\Delta v_{\rm FWHM}$ = 3.7 to 8.2 km s^{-1}) OH velocity component at a higher negative velocity ($v_{\rm LSR}$ = –4.8 to –3.3 km s^{-1}) that is identified as shocked gas; the H_2 mass in front of S106 from this component is $\sim 4\ M_\odot$. Our observations suggest an enhancement of the OH abundance in both velocity components by a factor of ~ 5 relative to dark clouds; the ratio $N_{\rm OH}/N_{\rm H_2} \approx 4 \times 10^{-7}$ and $N_{\rm OH}/A_{\rm v} \approx 5 \times 10^{14}$. This increased abundance is likely due to the penetration of UV photons into the molecular cloud resulting in enhanced OH formation. A line-of-sight magnetic field ($B_{\rm los}$) has been determined for the two OH velocity components between +150 and +400 μG over the inner arcminute (0.18 pc) of the HII region. The most significant detection of $B_{\rm los}$ in OH was +400 ± 23 μG about $0'.5$ (0.09 pc) northeast of the exciting source, IRS 4. Given simple assumptions about the geometry of the magnetic field and the mass distribution, the observed magnetic field appears to be near the critical value for magnetic support. Together with far IR and submm measurements of the direction of magnetic field in the plane of the sky, our Zeeman image of suggests that the field may lie along the long axis of S106 at large scales and be twisted into a toroidal morphology near the central star, IRS 4.

One of the HI velocity components appears to originate in shocked gas near the ionization front. This HI gas has a high negative radial velocity ($v_{\rm LSR}$ = –9.8 to –5.8 km s^{-1}), has a large line width ($\Delta v_{\rm FWHM}$ = 3.9 to 11.6 km s^{-1}), and is believed to be from shocked gas associated with the outflow. $B_{\rm los} \approx +70 \pm 12\ \mu$G for this velocity component near the center of the HII region. The small value of $B_{\rm los}$ determined for HI relative to OH may be due to a tangling of a strong field near the ionization front on scales smaller than our synthesized beamsize. A weak, narrow component with a velocity $\sim$–2 km s^{-1} is observed in the eastern portion of the source; this is probably unshocked HI in the molecular cloud. $B_{\rm los}$ in this unshocked component is estimated to be between +200 and +300 μG. The ratio of $N_{\rm HI}/N_{\rm H_2} \approx 2 \times 10^{-2}$ and 4×10^{-2} for the unshocked and shocked components, respectively. The increased strength of the shocked HI component is probably due to an increased relative abundance of HI from the photodissociation of H_2.

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The companion of HR 5999 in the near infrared

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The Herbig Ae/Be star HR 5999 has been observed by high-angular resolution techniques in the near infrared. The companion to HR 5999, Rossiter 3930, is clearly resolved. Several independent observations point to the possibility that this star is a T Tauri star. A motion of Rossiter 3930 in respect to HR 5999 was not detected. Both stars may form a common proper motion pair since their constellation did not change within about 60 years. We did not find evidence for disk-like or shell structures around HR 5999.

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Ginga Observation of the Orion B Cloud Region

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The Orion B cloud was observed with the Large Area Counter (LAC) onboard the X-ray satellite Ginga. Although the field of view of LAC included O-type stars, ζ Ori (O9.5 Ib) and σ Ori (O9.5 V), as well as the Orion B cloud, the contributions of ζ Ori and σ Ori were estimated to be less than $\sim$34% of the observed count rate by both extrapolating the result of the Einstein Observatory of ζ Ori and assuming that both ζ Ori and σ Ori have the same spectrum as that of δ Ori with a similar spectral type of O9.5 II. The X-ray spectrum after subtracting the contributions was well represented by a thin thermal plasma model with a temperature of 4.7 ± 0.6 keV. The best-fit abundance of iron was 0.25 ± 0.13 cosmic. Since many pre–main-sequence stars have been discovered in the Orion B cloud region, the origin of the thermal emission is considered to be the integrated emission from X-ray emitting pre–main-sequence stars embedded in the Orion B cloud. It follows from the results obtained in wide energy band observations that thermal emission with a temperature of several keV is a common characteristic of active star-forming regions.

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Line Formation in Collapsing Cloud Cores with Rotation and Applications to B335 and IRAS 16293-2422

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We present radiative transfer models of collapsing clouds with rotation and apply them to B335 and IRAS 16293−2422, the two best candidates of protostellar collapse known to date. By including rotation in the manner of Terebey, Shu, & Cassen (1984), we can reproduce the profiles of several molecular lines not only toward the center position, but also toward a grid of positions near the center. We find that the model of B335 by Zhou et al. (1993) is not affected significantly by the presence of rotation. By including rotation, we can reproduce the observations of IRAS 16293−2422 by Menten et al. (1987); hence, we support the infall interpretation of spectral lines from IRAS 16293−2422 proposed by Walker et al. (1986). We also observed the large-scale rotation of IRAS 16293−2422 in the $C^{18}O$ J = 2→1 line. The observed rotation rate is a factor of 6 smaller than that required to explain the small-scale CS data of Menten et al. (1987). This probably means that the pre-collapse cloud has differential rotation, possibly due to more efficient magnetic braking on large scales.

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Spectral line observations of two contrasting molecular clouds: Lynds 1630 and G34.3+0.2

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This thesis presents observations of two contrasting star forming molecular clouds, L1630 and G34.3+0.2, at millimetre and submillimetre wavelengths. L1630 is highly clumped and the regions studied are probably forming stars of low– to intermediate–mass. G34.3+0.2 is a group of at least four HII regions indicating that stars of predominantly high–mass are forming in this molecular cloud.

Six of 42 clumps identified in the CS survey of L1630 by Lada, Bally & Stark (1991 – LBS) have been observed in J=1–0, 3–2, 4–3 HCO^+ and 5–4 CS. From the 3–2 and 4–3 HCO^+ data, 22 maxima have been detected, 14 of which are associated with just two of the LBS 'clumps'. Most of these maxima are unresolved with 14–20$''$ resolution, and some are associated with known infrared sources. LBS23 (incorporating HH24–26) has been studied in more detail with complete maps made in CS and 4–3 HCO^+ and while the CS and HCO^+ have similar distributions, both exhibit significant spatial anti–correlation with NH_3. Three molecular outflows have been mapped in HH24–26 and LBS17 using 2–1 CO and 3–2 HCO^+.

The molecular cloud associated with the HII region G34.3+0.2 has been observed in ^{13}CO J=2–1, 3–2, 6–5, $C^{18}O$ 2–1 and CI $^3P_1$–$^3P_0$. In contrast to L1630, G34.3+0.2 appears as a single central maximum, with little evidence of small–scale clumping. Most of the lines show evidence of absorption, which is strongest at the centre of the HII regions. The emission also peaks at this position, but at least two other centres of activity are present within the cloud, not seen in previous maps. The emission of the CO and CI lines has been modelled using a spherically symmetric, non–LTE radiative transfer program. This model successfully reproduces the observed line intensities and shapes and predicts angular diameters which are in reasonable agreement with those observed.

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