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Abstracts of recently accepted papers

Morphology and kinematics of the Cepheus Bubble

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We investigate the spatial and velocity distribution of atomic hydrogen associated with the Cepheus Bubble, a giant ($\approx 10^\circ$ in angular diameter) dust ring around the Cep OB2 association. HI 21 cm data, taken from the Leiden/Dwingeloo survey, reveal HI structures in the $[-14, +2]$ kms^{-1} velocity range which can be associated with prominent parts of the dust ring. In the same area the HI maps also show an expanding shell with a well-defined approaching side at $V_{LSR} = -37 \text{ kms}^{-1}$ and a less well-defined receding side at $V_{LSR} \approx -4 \text{ kms}^{-1}$. The kinematics and size of this shell are best modelled by a supernova explosion, occurring in Cep OB2a at about 1.7 Myrs ago. Since the ages of several parts of the Cepheus Bubble are considerably higher than the age of the expanding shell, the supernova probably exploded in a pre-existing cavity, and its shock front might have interacted with the already existing star forming regions Sh2-140, IC 1396, and NGC 7129, leading to a new wave of star formation there.

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Early planet formation as a trigger for further planet formation

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Recent discoveries of extrasolar planets at small orbital radii, or with significant eccentricities, indicate that interactions between massive planets and the disks of gas and dust from which they formed are vital for determining the final shape of planetary systems. We show that if this interaction occurs at an early epoch, when the protoplanetary disc was still massive, then rapid planet growth through accretion causes an otherwise stable disc to fragment into additional planetary mass bodies when the planetary mass reaches 4-5 Jupiter masses. We suggest that such catastrophic planet formation could account for apparent differences in the mass function of massive planets and brown dwarfs, and the existence of young stars that appear to have dissipated their discs at an early epoch. Subsequent gravitational interactions will lead to planetary systems comprising a small number of massive planets in eccentric orbits.

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<http://xxx.lanl.gov/abs/astro-ph/9912147>

Theoretical interpretation of the apparent deceleration in the HH 34 superjet

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The HH 34 superjet shows a steep velocity decrease (from ~ 500 to ~ 100 km s⁻¹) over a distance of ~ 2 pc on either side of the central source. We explore whether or not this behaviour could be interpreted as evidence for a slow “turning on” of the ejection velocity of the jet, and find that this is indeed possible, but only for an ejection velocity that has had a dramatic growth over the last $\sim 10^4$ yr, and is just about to stabilize within the next 4000 yr. We argue that such a time-variability is somewhat unlikely.

We then explore a second scenario, in which the slowing down of the HH 34 superjet is modeled as the result of the interaction of a fragmented jet with the surrounding environment. We find that for parameters appropriate for HH 34, this model does appear to reproduce the observed slowing down of the superjet in a natural way. We therefore conclude that the kinematical properties of the HH 34 superjet are most likely to be the result of environmental drag on the propagation of individual jet knots, resulting from the fragmentation of a time-variable, precessing jet.

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Magnetized accretion-ejection structures

IV. Magnetically-driven jets from resistive, viscous, Keplerian discs

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We present steady-state calculations of self-similar magnetized accretion discs driving cold, adiabatic, non-relativistic jets. For the first time, both the magnetic torque due to the jets and a turbulent “viscous” torque are taken into account. This latter torque allows a dissipation of the accretion power as radiation at the disc surfaces, while the former predominantly provides jets with power.

The parameter space of these structures has been explored. It is characterized by four free parameters, namely the disc aspect ratio and three MHD turbulence parameters, related to the anomalous magnetic diffusivities and viscosity. It turns out that launching cold jets from thin, dissipative discs implies anisotropic turbulent dissipation. Jets that asymptotically reach a high Alfvénic Mach number are only produced by weakly dissipative discs.

We obtained general analytical relations between disc and jet quantities that must be fulfilled by any steady-state model of cold jets, launched from a large radial extension of thin discs. We also show that such discs cannot have a dominant viscous torque. This is because of the chosen geometry, imposing the locus of the Alfvén surface.

Some observational consequences of these cold magnetized accretion-ejection structures are also briefly discussed.

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Submillimeter Polarimetry of the Protostellar Outflow Sources in Serpens with SCUBA

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Submillimeter (SMM) polarimetric measurements of the 850 μ m dust continuum emission associated with the Class 0/I protostars in the Serpens Dark Cloud core are presented. The data are used to infer the magnetic field morphology in the region. Dust grain alignment in accretion flows and/or outflows is also briefly considered. The polarisation vectors

around the SMM-NW cluster of sources are more ordered than those observed near the SMM-SE cluster. Towards SMM-NW the vectors are generally orientated north-south; between the intensity peaks in the SMM-SE region the vectors are approximately east-west. In both regions we suggest that the polarisation pattern may be dictated by a large scale magnetic field. We consider whether the rough NW-SE ridge of submm sources was formed via cloud collapse along field lines that run perpendicular to this ridge. However, our data offer only very tentative support for this hypothesis. We further note that, although overall the polarisation pattern in Serpens does not appear to be affected by the many outflows in the region, towards the most luminous source, SMM 1, the source of the Serpens Radio Jet, the vectors deviate considerably from the general pattern, instead being roughly perpendicular to the flow axis, as one would expect from a B-field orientated parallel with the flow.

Accepted by *Astrophys J. Letters*

Preprints available from: <http://www.jach.hawaii.edu/~cdavis/papers.html>

Parsec-scale molecular H₂ outflows from young stars

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Deep imaging in the 1-0 S(1) line of molecular hydrogen was used to search for parsec-scale molecular outflows in L1448, NGC 2071, and NGC 7129. Apart from seven parsec-scale flows, 21 other, shorter molecular outflows were found. This means that on average 25% of the molecular flows are of parsec-scale length, with a variation from 17 to 50% in the three observed regions.

For the 28 outflows, only eight driving sources could be identified with near-infrared sources or nebulosity in our images. Six further sources likely are known deeply embedded Class 0 objects, while for 14 flows no sources could be identified. Therefore, these objects presumably are also deeply embedded, and are good Class 0 candidates.

We find no evidence for different absolute lengths of the parsec-scale molecular flows from known Class 0 and Class I sources in the observed regions, i.e. the length of these flows is not indicative of their true age. These flows have broken out of their cloud cores and likely are moving through a medium too tenuous to produce further visible shock emission. Moreover, even for the flows from the Class 0 sources we derive kinematical ages of up to 2×10^4 years, comparable to the lifetime of these sources, and indicating that outflow activity must start very early in the Class 0 phase of star formation, or even before.

Four molecular H₂ outflows with a high degree of curvature are found in our sample, and mechanisms for their bending are discussed.

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Preprints are available at <http://www.tls-tautenburg.de/research/research.html>

Two Stellar Mass Functions Combined into One by the Random Sampling Model of the IMF

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The turnover in the stellar initial mass function (IMF) at low mass suggests the presence of two independent mass functions that combine in different ways above and below a characteristic mass given by the thermal Jeans mass in the cloud. In the random sampling model introduced earlier, the Salpeter IMF at intermediate to high mass follows primarily from the hierarchical structure of interstellar clouds, which is sampled by various star formation processes and converted into stars at the local dynamical rate. This power law part is independent of the details of star formation inside each clump and therefore has a universal character. The flat part of the IMF at low mass is proposed here to result from a second, unrelated, physical process that determines only the probability distribution function for final star mass inside a clump of a given mass, and is independent of both this clump mass and the overall cloud structure. Both processes operate for all potentially unstable clumps in a cloud, regardless of mass, but only the first shows up

above the thermal Jeans mass, and only the second shows up below this mass. Analytical and stochastic models of the IMF that are based on the uniform application of these two functions for all masses reproduce the observations well.

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Reconnection X-winds: spin-down of low-mass protostars

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We investigate the interaction of a protostellar magnetosphere with a large-scale magnetic field threading the surrounding accretion disc. It is assumed that a stellar dynamo generates a dipolar-type field with its magnetic moment aligned with the disc magnetic field. This leads to a magnetic neutral line at the disc midplane and gives rise to magnetic reconnection, converting closed protostellar magnetic flux into open field lines. These are simultaneously loaded with disc material, which is then ejected in a powerful wind. This process efficiently brakes down the protostar to 10–20 per cent of the break-up velocity during the embedded phase.

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<http://www-laog.obs.ujf-grenoble.fr/ferreira/publi/mhd.html>

Small-scale Structure of the Circumstellar Gas Around The Very Young Outflow-Driving Source L483-FIR

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A remarkable young stellar object in L483 numbers among the fewer than a dozen known youngest protostars, those with 'Class 0' spectral energy distributions. We report high angular and spectral resolution images of bright NH₃(1, 1) and NH₃(2, 2) line emission arising from the molecular gas near this object. Along the ridge of dense gas traced by the NH₃(1, 1) emission there is a velocity gradient of ~ 4 km/s/pc. We also report images of dust emission at 450 μ m and 850 μ m. The images correspond well over scales of thousands of AU. Near the star, however, the ammonia map corresponds in detail more closely with an image taken at 3.4 μ m than to the submillimeter images in that absorption in the near infrared corresponds to an emission deficit in the ammonia maps. In the region of the deficit, the ammonia (1,1) line displays high optical depths, and its velocity is blueshifted relative to nearby gas, and to other molecular lines emanating from the region. We offer a specific model incorporating infall from the surrounding core onto the region within 3000 AU of the protostar.

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A postscript version of the paper is available from <http://dione.phy.umist.ac.uk/Papers/1483.ps.gz>

or <http://saturn.phy.umist.ac.uk:8000/~gaf/Papers.html>

Discovery of a dense bipolar outflow from a new class 0 protostar in NGC 2068/LBS 17

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We report the discovery of high-velocity dense gas from a bipolar outflow source near NGC 2068 in the L 1630 giant

molecular cloud. CO and HCO⁺ $J=3-2$ line wings have a bipolar distribution in the vicinity of LBS 17-H with the flow orientated roughly east-west and perpendicular to the elongation of the submillimetre dust continuum emission. The flow is compact (total extent ~ 0.2 pc) and contains of order $0.1 M_{\odot}$ of swept-up gas. The high-velocity HCO⁺ emission is distributed over a somewhat smaller area <0.1 pc in extent.

A map of C¹⁸O $J=2-1$ emission traces the LBS 17 core and follows the ambient HCO⁺ emission reasonably well, with the exception of towards LBS 17-H where there is a significant anti-correlation between the C¹⁸O and HCO⁺. A comparison of beam-matched C¹⁸O and dust-derived H₂ column densities suggests that CO is depleted by up to a factor of ~ 50 at this position if the temperature is as low as 9 K, although the difference is substantially reduced if the temperature is as high as 20 K. Chemical models of collapsing clouds can account for this discrepancy in terms of different rates of depletion onto dust grains for CO and HCO⁺.

LBS 17-H has a previously-known water maser coincident with it but there are no known near-infrared, IRAS or radio continuum sources associated with this object, leading to the conclusion that it is probably very young. A greybody fit to the continuum data gives a luminosity of only $1.7 L_{\odot}$ and a submillimetre-to-bolometric luminosity ratio of 0.1, comfortably satisfying the criteria for classification as class 0 protostar candidate.

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A postscript version may be obtained from <http://ast.leeds.ac.uk/~agg/research/pubs.html>

Resolving Molecular Line Emission from Protoplanetary Disks: Observational Prospects for Disks Irradiated by Infalling Envelopes

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Molecular line observations that could resolve protoplanetary disks of ~ 100 AU both spatially and kinematically would be a useful tool to unambiguously identify these disks and to determine their kinematical and physical characteristics. In this work we model the expected line emission from a protoplanetary disk irradiated by an infalling envelope, addressing the question of its detectability with subarcsecond resolution. We adopt a previously determined disk model structure that gives a continuum spectral energy distribution and a mm intensity spatial distribution that are consistent with observational constraints of HL Tau. An analysis of the capability of presently working and projected interferometers at mm and submm wavelengths shows that molecular transitions of moderate opacity at these wavelengths (e.g., C¹⁷O lines) are good candidates for detecting disk lines at subarcsecond resolution in the near future. We suggest that, in general, disks of typical Class I sources will be detectable. Higher line intensities are obtained for lower inclination angles, larger turbulent velocities, and higher temperatures, with less effect from density changes.

The resulting maps show several characteristics that can be tested observationally. A clear asymmetry in the line intensity, with more intense emission in the disk area farther away from the observer, can be used to compare the geometrical relationship between disks and outflows. A decrease in intensity towards the center of the disk is also evident. Finally, the emission peaks in position velocity diagrams trace mid-plane Keplerian velocities.

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Kinematics of Herbig-Haro Objects in the Protostellar Outflow L 1551 as Mapped by Fabry-Perot Spectroscopy

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We present new velocity-resolved Fabry-Perot images in [S II] $\lambda 6731$ and $H\alpha$ of the blueshifted portion of the protostellar outflow L 1551. These new data isolate the line emission from the reflected continuum, and make it possible to visualize the kinematics of the shock waves in the outflow clearly for the first time on large size scales with subarcsecond spatial resolution.

Velocity images of the L 1551 jet confirm that a fainter, slower jet lies a few arcseconds below the main jet. Emission from the main jet decreases sharply in radial velocity and the emission line width increases suddenly as the jet encounters the bright knot #3, in agreement with bow shock models. This knot must move into previously ejected material to account for the observed radial velocities, supporting the idea that shocks in HH flows form as the result of variable velocity ejections from the embedded protostar. However, a velocity gradient observed along the entire edge of the bow shock is spatially larger than expected if the bow shock alone were responsible for all the line emission. Deviations from the simple model are most easily explained if a Mach disk alters the emission and kinematics within the bow shock region, though a precursor to the bow shock is an alternate possibility.

The spatial distribution of radial velocities and emission line widths across HH 29 implies that this object is a slower portion of the outflow currently being overtaken by faster material. New proper motion images of HH 29 independently confirm this result. The large-scale velocity structure of the L 1551 outflow is complex, but can generally be understood if faster material drives shock waves into slower material around the edge of a cavity. A striking circular feature whose center lies near the intersection of the axis of the bright jet and the cavity resembles similar structures in the Orion Nebula, and could define a hole through which a fast jet has penetrated. The velocity structure along a string of HH objects to the southwest of HH 29 is consistent with the result of Devine et al. (1999) that L 1551 NE drives this portion of the outflow. Linear features that cross the L 1551 flow may be associated with separate, unrelated jets from the HH 30 region or elsewhere within L 1551.

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A copy of the paper is available at <http://sparky.rice.edu/~hartigan/pub.html>.

A $C^{17}O$ Survey Toward Ultracompact HII Regions

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We have observed 16 regions of massive star formation in the $J = 1-0$, $2-1$ rotational transitions of $C^{17}O$ and the $J = 2-1$ transition of $C^{18}O$ with the IRAM 30m telescope. We have also observed the $J = 2-1$, $3-2$ rotational transitions of $C^{17}O$ with the KOSMA 3m telescope. The $C^{17}O$ emitting clumps typically have sizes of 1 pc, average densities and temperatures of 10^5 cm^{-3} and 25 K, respectively. Clump masses from 10^3 to $4 \times 10^4 M_{\odot}$ are found and most of the clumps are virialised in the sense that their gravitational energy is of the same order as bulk kinetic energy inferred from the linewidth. We also compare the derived masses with values obtained using measurements of the mm/submm dust continuum emission and find that the dust continuum masses tend to be higher by about a factor of 2. We estimate the masses of early type stars (more massive than $15 M_{\odot}$) embedded in the sources of our sample and conclude that the ratio of “O-star mass” to gas mass is roughly one percent in most cases.

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Testing envelope models of young stellar objects with submillimeter continuum and molecular-line observations

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Theoretical models of star formation make predictions about the density and velocity structure of the envelopes surrounding isolated, low-mass young stars. This paper tests such models through high quality submillimeter continuum imaging of four embedded young stellar objects in Taurus and previously obtained molecular-line data. Observations carried out with the Submillimeter Continuum Bolometer Array on the James Clerk Maxwell Telescope at 850 and 450 μm of L1489 IRS, L1535 IRS, L1527 IRS, and TMC 1 reveal ~ 2000 AU elongated structures embedded in extended envelopes. The density distribution in these envelopes is equally well fit by a radial power-law of index $p = 1.0\text{--}2.0$ or with a collapse model such as that of Shu (1997: ApJ, 214, 488). This inside-out collapse model predicts ^{13}CO , C^{18}O , HCO^+ , and H^{13}CO^+ line profiles which closely match observed spectra toward three of our four sources. This shows that the inside-out collapse model offers a good description of YSO envelopes, but also that reliable constraints on its parameters require independent measurements of the density and the velocity structure, e.g., through continuum and line observations. For the remaining source, L1489 IRS, we find that a model consisting of a 2000 AU radius, rotating, disk-like structure better describes the data. Possibly, this source is in transition between the embedded Class I and the optically revealed T Tauri phases. The spectral index of the dust emissivity decreases from $\beta = 1.5\text{--}2.0$ in the extended envelope to 1.0 ± 0.2 in the central peaks, indicating grain growth or high optical depth on small scales. The observations of L1527 IRS reveal warm ($> \sim 30$ K) material outlining, and presumably heated by, its bipolar outflow. This material comprises $< \sim 0.2 M_{\odot}$, comparable to the amount of swept-up CO but only 10% of the total envelope mass. Two apparently starless cores are found at $\sim 10,000$ AU from L1489 IRS and L1535 IRS. They are cold, 10–15 K, contain 0.5–3.0 M_{\odot} , and have flat density distributions characterized by a Gaussian of $\sim 10,000$ AU FWHM. The proximity of these cores shows that star formation in truly isolated cores is rare even in Taurus.

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Preprints are available at <http://astro.berkeley.edu/~michiel>

Fragmentation Instability of Molecular Clouds: Numerical Simulations

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We simulate fragmentation and gravitational collapse of cold, magnetized molecular clouds. We explore the nonlinear development of an instability mediated by ambipolar diffusion, in which the collapse rate is intermediate between fast gravitational collapse and slow quasistatic collapse. Initially uniform, stable clouds fragment into elongated clumps with masses largely determined by the cloud temperature, but substantially larger than the thermal Jeans mass. The clumps are asymmetric, with significant rotation and vorticity, and lose magnetic flux as they collapse. The clump shapes, intermediate collapse rates, and infall profiles may help explain observations not easily fit by contemporary slow or rapid collapse models

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Physical State of Molecular Gas in High Galactic Latitude Translucent Clouds

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The rotational transitions of carbon monoxide (CO) are the primary means of investigating the density and velocity structure of the molecular interstellar medium. Here we study the lowest four rotational transitions of CO towards high-latitude translucent molecular clouds (HLCs). We report new observations of the $J = (4-3)$, $(2-1)$, and $(1-0)$ transitions of CO towards eight high-latitude clouds. The new observations are combined with data from the literature to show that the emission from *all* observed CO transitions is linearly correlated. This implies that the excitation

conditions which lead to emission in these transitions are uniform throughout the clouds. Observed $^{13}\text{CO}/^{12}\text{CO}$ (1–0) integrated intensity ratios are generally much greater than the expected abundance ratio of the two species, indicating that the regions which emit CO $J = (1-0)$ radiation are optically thick. We develop a statistical method to compare the observed line ratios with models of CO excitation and radiative transfer. This enables us to determine the most likely portion of the physical parameter space which is compatible with the observations. The model enables us to rule out CO gas temperatures greater than ~ 30 K, since the most likely high-temperature configurations are 1 pc -sized structures aligned along the line of sight. The most probable solution is a high density and low temperature (HDLT) solution, with volume density, $n = 10^{4.5\pm 0.5} \text{ cm}^{-3}$, kinetic temperature, $T_k \approx 8$ K, and CO column density per velocity interval $N_{\text{CO}}/\Delta V = 10^{16.6\pm 0.3} \text{ cm}^{-2}/(\text{km s}^{-1})$. The CO cell size is $L \sim 0.01$ pc (~ 2000 AU). These cells are thus tiny fragments within the ~ 100 times larger CO-emitting extent of a typical high-latitude cloud. We discuss the physical implications of HDLT cells, and we suggest ways to test for their existence.

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Preprints available at <http://spider.ipac.caltech.edu/ingalls>

A Pair of Twisted Jets of Ionized Iron from L1551-IRS 5

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High-resolution near-infrared J -band imaging with the Subaru Telescope has demonstrated, for the first time from the ground, two independent jets emanating from the protostar L1551-IRS 5. Successive near-infrared spectroscopy has revealed that the jet emission is dominated by [Fe II] lines in the J and H -bands. While the visual extinction estimated from [Fe II] line ratios reaches more than 20 mag in the close vicinity of IRS 5, it decreases rapidly at $\sim 1''$ from IRS 5 and remains constant around 7 mag at larger distances. The electron density in the jets is estimated to be 10^6 cm^{-3} near IRS 5 and is 10^4 to 10^5 cm^{-3} in their outer section. The twisted appearance of the jets, with bright knots especially prominent in the northern jet, is similar to the R -band jets observed with the Hubble Space Telescope. These results suggest that the twisted structure and bright emission knots are intrinsic to the jets and are not due to the spatial variation of extinction.

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Dense Cores mapped in Ammonia - A Database

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We present a database of 264 cores mapped in the $(J, K) = (1, 1)$ and $(2, 2)$ lines of NH_3 . We list the core gas properties - peak positions, total ammonia column densities, intrinsic linewidths, kinetic temperatures, volume densities, core sizes, aspect ratios and velocity gradients, as well as the properties of associated YSOs - associated IRAS sources along with their luminosities and core-YSO distances, outflow velocities, SIMBAD and cluster associations. We also present the results of our statistical analysis and enumerate important pairwise correlations amongst the various gas and YSO properties. The results indicate that the association of stellar clusters with star forming cores has a greater impact on their properties than does the presence of associated YSOs within these cores although the latter influence is also statistically significant. In other words, the difference in core properties (nonthermal linewidths, kinetic temperatures, core sizes) between cores with and without associated YSOs is less significant when compared with the difference in these properties between cores with and without cluster associations. Furthermore, core gas and YSO properties show a significant dependence on the star forming region in which the core is located. For instance, cores in Orion have larger linewidths, higher kinetic temperatures and larger sizes as compared with cores in Taurus. Similarly, YSOs

in Orion are more luminous than those in Taurus. These cluster and regional dependencies seem important enough that they ought to be accounted for in any self consistent theory of star formation. Finally, the ratio of starless to stellar cores is too small (8/12 in Taurus, 2/41 in Orion A) cores is too small (8/12 in Taurus, 2/41 in Orion A) to be consistent with ambipolar diffusion time scales which predict ratios as high as 3 – 30. This result is true even for regions that are known to be well surveyed and to not suffer from significant sample biases.

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http://adsabs.harvard.edu/cgi-bin/bib_query?bibcode=1999CfA....RG.4794J&db_key=CFA

Multiplicity of X-ray selected T Tauri Stars in the Scorpius-Centaurus OB Association

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We report the results of a search for binarity among young stars, performed in the Scorpius-Centaurus OB association on a sample of 118 X-ray selected T Tauri stars. We use speckle interferometry and direct-imaging observations to find companions in the separation range $0.13'' - 6''$. After corrections to account for confusion with background stars and for the bias induced by the X-ray selection, we find a multiplicity (number of binaries or multiples divided by number of systems) of $(32.6 \pm 6.1)\%$, and a number of companions per system of $(35.2 \pm 6.3)\%$. This is higher by a factor of 1.59 ± 0.34 compared to main-sequence stars, but slightly lower than in a sample in the Taurus-Auriga star-forming region that was selected and studied similarly. In Scorpius-Centaurus, we find fewer binaries with nearly equal brightness than in Taurus-Auriga. There are significant differences between the period distributions in the two subgroups Upper Scorpius A and B: The peak of the distribution of stars in US-A is at about 10^5 days, while that of stars in US-B is around $10^{6.5}$ days. We compared our results with the optical multiplicity survey of Brandner et al. (1996), whose sample contains 49 stars that were also observed by us, and find no infrared companions. The flux ratio distributions of close and wide binaries in our sample show no significant difference.

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Preprint available at <http://www.aip.de/~koehler/Papers/>

33.8 GHz CCS Survey of Molecular Cores in Dark Clouds

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We have conducted a survey of the CCS $J_N = 3_2 - 2_1$ line toward 11 dark clouds and star-forming regions at $30''$ spatial resolution and 0.054 km/s velocity resolution. CCS was only detected in quiescent clouds, not in active star-forming regions. The CCS distribution shows remarkable clumpy structure, and 25 clumps are identified in 7 clouds. Seven clumps with extremely narrow nonthermal linewidths $< 0.1 \text{ km s}^{-1}$ are among the most quiescent clumps ever found. The CCS clumps tend to exist around the higher density regions traced by NH_3 emission or submillimeter continuum sources, and the distribution is not spherically symmetric. Variation of the CCS abundance was suggested as an indicator of the evolutionary status of star formation. However, we can only find a weak correlation between $N(\text{CCS})$ and $n_{\text{H}_2, \text{vir}}$. The velocity distributions of CCS clouds reveal that a systematic velocity pattern generally exists. The most striking feature in our data is a ring structure in the position-velocity diagram of L1544 with a well-resolved inner hole of $0.04 \text{ pc} \times 0.13 \text{ km s}^{-1}$ and an outer boundary of $0.16 \text{ pc} \times 0.55 \text{ km s}^{-1}$. This position-velocity structure clearly indicates an edge-on disk or ring geometry, and it can be interpreted as a collapsing disk with an infall velocity $\geq 0.1 \text{ km s}^{-1}$ and a rotational velocity less than our velocity resolution. Nonthermal linewidth distribution is generally coherent in CCS clouds, which could be evidence for the termination of Larson's Law at small scales, $\sim 0.1 \text{ pc}$.

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Structure and Stability of Keplerian MHD Jets

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MHD jet equilibria that depend on source properties are obtained using a simplified model for stationary, axisymmetric and rotating magnetized outflows. The present rotation laws are more complex than previously considered and include a Keplerian disc. The ensuing jets have a dense, current-carrying central core surrounded by an outer collar with a return current. The intermediate part of the jet is almost current-free and is magnetically dominated. Most of the momentum is located around the axis in the dense core and this region is likely to dominate the dynamics of the jet. We address the linear stability and the non-linear development of instabilities for our models using both analytical and 2.5-D numerical simulations. The instabilities seen in the simulations develop with a wavelength and growth time that are well matched by the stability analysis. The modes explored in this work may provide a natural explanation for knots observed in astrophysical jets.

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preprints may be found at <http://xxx.lanl.gov/astro-ph/9912328>

The Formation and Structure of a Strongly Magnetized Corona above Weakly Magnetized Accretion Disks

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We use three-dimensional magnetohydrodynamical (MHD) simulations to study the formation of a corona above an initially weakly magnetized, isothermal accretion disk. The simulations are local in the plane of the disk, but extend up to 5 vertical scaleheights above and below it. We describe a modification to time-explicit numerical algorithms for MHD which enables us to evolve such highly stratified disks for many orbital times. We find that for initially toroidal fields, or poloidal fields with a vanishing mean, MHD turbulence driven by the magnetorotational instability (MRI) produces strong amplification of weak fields within two scale heights of the disk midplane in a few orbital times. Although the primary saturation mechanism of the MRI is local dissipation, about 25% of the magnetic energy generated by the MRI within two scale heights escapes due to buoyancy, producing a strongly magnetized corona above the disk. Most of the buoyantly rising magnetic energy is dissipated between 3 and 5 scale heights, suggesting the corona will also be hot. Strong shocks with Mach numbers ≥ 2 are continuously produced in the corona in response to mass motions deeper in the disk. Only a very weak mass outflow is produced through the outer boundary at 5 scale heights, although this is probably a reflection of our use of the local approximation in the plane of the disk. On long timescales the average vertical disk structure consists of a weakly magnetized ($\beta \sim 50$) turbulent core below two scale heights, and a strongly magnetized ($\beta \leq 10^{-1}$) corona which is stable to the MRI above. The largescale field structure in both the disk and the coronal regions is predominately toroidal. Equating the volume averaged heating rate to optically thin cooling curves, we estimate the temperature in the corona will be of order 10^4 K for protostellar disks, and 10^8 K for disks around neutron stars. The functional form of the stress with vertical height is best described as flat within $\pm 2H_z$, but proportional to the density above $\pm 2H_z$.

For initially weak uniform vertical fields, we find the exponential growth of magnetic field via axisymmetric vertical modes of the MRI produces strongly buoyant sheets of magnetic energy which break the disk apart into horizontal channels. These channels rise several scale heights vertically before the onset of the Parker instability distorts the sheets and allows matter to flow back towards the midplane and reform a disk. Thereafter the entire disk is magnetically dominated and not well modeled by the local approximation. We suggest this evolution may be relevant to the dynamical processes which disrupt the inner regions of a disk when it interacts with a strongly magnetized central object.

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Silicate Emission in T Tauri Stars: Evidence for Disk Atmospheres?

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We present low-resolution mid-infrared spectra of nine classical T Tauri stars associated with the Chamaeleon I dark cloud. The data were obtained with the PHOT-S instrument on-board the Infrared Space Observatory (ISO) in the two wavelength ranges 2.5–4.9 and 5.9–11.7 μm . All nine stars show evidence of silicate emission at 10 μm , which is the only prominent feature in the spectra. We discuss a model for the origin of these features in a hot optically-thin surface layer of the circumstellar disks surrounding the central young stars (i.e. a disk atmosphere). We report excellent agreement of our observations with predictions based upon this simple model for most stars in our sample, assuming that a mixture of amorphous silicates of radius $\sim < 1 \mu\text{m}$ is the dominant source of opacity. These observations support the notion that extended disk atmospheres contribute substantially to the mid-IR flux of young stars.

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<http://www.arcetri.astro.it/starform/publ1999.htm> or <http://gould.as.arizona.edu/origins/preprint.html>

Multiplicity of the massive stars in the Orion Nebula cluster

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We present bispectrum speckle interferometry observations of 13 bright Orion Nebula cluster member stars of spectral type O or B. Diffraction-limited images with a resolution λ/D of 75 mas in the K' -band were obtained with the SAO 6 m telescope. In our speckle images we find 8 visual companions in total. Using the flux ratios of the resolved systems to estimate the masses of the companions, we find that the systems generally have mass ratios below 1/2. The distribution of mass ratios seems to be consistent with a companion mass function similar to the field IMF. Considering both the visual and the spectroscopic companions of the 13 target stars, the total number of companions is at least 14. Extrapolation with correction for the unresolved systems suggests that there are *at least 1.5 companions per primary star on average*. This number is clearly higher than the mean number of ~ 0.5 companions per primary star found for the low-mass stars in the Orion Nebula cluster as well as in the field population. This suggests that a different mechanism is at work in the formation of high-mass multiple systems in the dense Orion Nebula cluster than for low-mass stars.

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<http://www.mpifr-bonn.mpg.de/staff/tpreibis/onc-bin.html>

Hubble Space Telescope NICMOS and WFPC2 Images of the HH 1 Jet: A Comparative Study

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We present new *HST* NICMOS images of the source region of the HH 1/2 flow. The HH 1 jet is traced in the [FeII] 1.64 μm and the H₂ 2.12 μm lines to about 2.5'' of the deeply embedded VLA source. In general the structure of the jet is similar in H₂ and [FeII] with all the features having comparable brightness in both species. However, there is a

gradient in the $\text{H}_2/[\text{FeII}]$ ratio which increases with distance from the source. We also compare our infrared images with almost contemporary *HST* WFPC2 images in $\text{H}\alpha$ and $[\text{SII}]$. The ratio of $[\text{FeII}]$ to $[\text{SII}]$, both low-excitation tracers of weak shocks, is almost constant along the visible part of the jet, but then increases by an order of magnitude where the optical jet disappears. If this is due to reddening, then the extinction, A_V , increases by at least 4 magnitudes in a space of $0.9''$, corresponding to 420 AU. Beyond this obscuring ridge, we detect five more infrared knots. Less than $2''$ now separate the infrared jet and the tip of the compact 3.6 cm radio continuum jet centered on the VLA source. The heavy extinction which obscures the base of the IR jet is probably due to the compact cloud core recently detected in HCO^+ . The jet is observed to steadily increase in width, and we argue that this is either due to sideways ejection of shocked material from internal working surfaces, or a sonic expansion of the hot jet beam. Surprisingly the width of the jet is the same to within measurement errors in H_2 and $[\text{FeII}]$, contrary to the expectations of some models. Two small, previously detected off-axis knots appear to form an independent HH flow, which we call HH 501. An infrared cometary nebula (dubbed the X nebula) is found next to the HH 1 jet, along a line through the HH 501 knots, possibly supporting earlier speculations that yet one more source exists in the region. However, new proper motions of the HH 501 flow suggest an origin of these knots near VLA 1, and it is therefore possible that the VLA 1 source itself may be a close binary, thus forming a triple system with the more distant VLA 2.

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VLA OH and HI Zeeman Observations of the NGC 6334 Complex

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We present OH and HI Zeeman observations of the NGC 6334 complex taken with the Very Large Array. The OH absorption profiles associated with the complex are relatively narrow ($\Delta v_{\text{FWHM}} \sim 3 \text{ km s}^{-1}$) and single-peaked over most of the sources. The HI absorption profiles contain several blended velocity components. One of the compact continuum sources in the complex (source A) has a bipolar morphology. The OH absorption profiles toward this source display a gradient in velocity from the northern continuum lobe to the southern continuum lobe; this velocity gradient likely indicates a bipolar outflow of molecular gas from the central regions to the northern and southern lobes. Magnetic fields of the order of 200 μG have been detected toward three discrete continuum sources in the complex. Virial estimates suggest that the detected magnetic fields in these sources are of the same order as the critical magnetic fields required to support the molecular clouds associated with the sources against gravitational collapse.

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Preprints available at http://www.pa.uky.edu/~sarma/RESEARCH/aps_research.html

The Molecular Outflow and Possible Precessing Jet from the Massive Young Stellar Object IRAS 20126+4104

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We present images of the molecular gas in the IRAS 20126+4104 massive outflow and examine the interaction between the energetic outflowing material and the surrounding molecular cloud. Mosaic interferometric images in $\text{CO}(1-0)$, $^{13}\text{CO}(1-0)$, $\text{C}^{18}\text{O}(1-0)$, $\text{C}^{17}\text{O}(1-0)$, and millimeter continuum emission are compared with mid-infrared images at $12.5 \mu\text{m}$ & $17.9 \mu\text{m}$, near-infrared images in the K_s band ($2.17 \mu\text{m}$) and H_2 line emission, and optical $\text{H}\alpha$ and $[\text{SII}]$ images. We show that the molecular outflow is approximately 6×10^4 years old with a mass of about 50-60 M_\odot and mass outflow rate $\dot{M}_f \sim 8 \times 10^{-4} M_\odot \text{ yr}^{-1}$. The driving source is located near the center of the $\gtrsim 300 M_\odot$ molecular

cloud and the mass of the disk plus circumstellar envelope traced by millimeter continuum emission is $\sim 50 M_{\odot}$. The outflow appears to be bounded on most sides by higher density gas traced by $C^{18}O$ emission. Shocks identified by H_2 and [SII] emission knots follow a NW-SE jet close to the young stellar object and then rotate more N-S along the edges of the CO flow. The most likely interpretation appears to be that the knots trace the working surfaces of a collimated jet which precesses through an angle of $\sim 45^\circ$. Possible mechanisms that could produce the jet precession include tidal interactions between the disk and a companion star in a non-coplanar orbit or an anisotropic accretion event that dramatically altered the angular momentum vector of the disk.

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<http://www.aoc.nrao.edu/~dshepher/>

Quasi-periodic X-ray Flares from the Protostar YLW15

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With *ASCA*, we have detected three X-ray flares from the Class I protostar YLW15. The flares occurred every ~ 20 hours and showed an exponential decay with time constant 30–60 ks. The X-ray spectra are explained by a thin thermal plasma emission. The plasma temperature shows a fast-rise and slow-decay for each flare with $kT_{peak} \sim 4$ –6 keV. The emission measure of the plasma shows this time profile only for the first flare, and remains almost constant during the second and third flares at the level of the tail of the first flare. The peak flare luminosities $L_{X,peak}$ were ~ 5 – 20×10^{31} erg s⁻¹, which are among the brightest X-ray luminosities observed to date for Class I protostars. The total energy released in each flare was 3 – 6×10^{36} ergs. The first flare is well reproduced by the quasi-static cooling model, which is based on solar flares, and it suggests that the plasma cools mainly radiatively, confined by a semi-circular magnetic loop of length $\sim 14 R_{\odot}$ with diameter-to-length ratio ~ 0.07 . The two subsequent flares were consistent with the reheating of the same magnetic structure as of the first flare. The large-scale magnetic structure and the periodicity of the flares imply that the reheating events of the same magnetic loop originate in an interaction between the star and the disk due to the differential rotation.

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The SiO and CS emission in the Molecular Outflow toward L1157

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We present observational studies of the molecular outflow associated with the Class 0 young stellar object toward L1157. The CO emission shows a well collimated bipolar morphology with rich structure. In addition to the extended emission, the CO gas is found in clumps in the vicinity of the near infrared H_2 emission. The SiO emission is seen in six prominent condensations, three on each side of the protostar. They appear to be in three pairs; each pair aligns well with the exciting star. The CS emission imaged toward the blue-shifted outflow is well collimated and presents a bow-shaped structure coincident with the SiO and H_2 . A comparison of the outflow in different tracers suggests that the molecular gas is entrained at the head of an underlying jet. The jet seems to be episodic and shows signs of deceleration as it ploughs through the dense core.

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

Special NANTEN issue of Pub. Astr. Soc. Japan

The following 14 papers form a PASJ special issue presenting the first results from the NANTEN telescope, which is a 4-m diameter mm-wave telescope of Nagoya University located at Las Campanas Observatory in Chile.

The papers are accepted by Publ. Astron. Soc. Japan and will appear in Vol. 51, No. 6, 1999; (NANTEN special issue)

Preprints available at <http://www.a.phys.nagoya-u.ac.jp/NANTEN-PASJ/>

First Results of a CO Survey of the Large Magellanic Cloud with NANTEN; Giant Molecular Clouds as Formation Sites of Populous Clusters

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A new survey of the LMC has been completed in 2.6 mm carbon monoxide emission with NANTEN. This survey has revealed 107 giant molecular clouds, the first complete sample of giant molecular clouds in a single galaxy at a linear resolution of ~ 40 pc. The cloud mass ranges from $\sim 6 \times 10^4$ to $2 \times 10^6 M_\odot$, and the total molecular mass has been estimated to be $4\text{--}7 \times 10^7 M_\odot$ for a molecular column density of $\geq 1.0 \times 10^{21} \text{ cm}^{-2}$, corresponding to 5–10% of the atomic mass. The molecular clouds exhibit a good spatial correlation with the youngest stellar clusters whose ages are ≤ 10 Myr, demonstrating that cluster formation is on-going in these clouds. On the other hand, they show little correlation with older clusters or with supernova remnants, suggesting that the molecular clouds are being rapidly dissipated in a several Myrs, probably due to the UV photons of massive stars in clusters.

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Discovery of the Carina Flare with NANTEN; Evidence for a Supershell That Triggered the Formation of Stars and Massive Molecular Clouds

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We present extensive observations of the Carina arm region in the 2.6 mm CO ($J = 1\text{--}0$) emission with the NANTEN telescope in Chile. The observations have revealed 120 molecular clouds which are distributed in an area of $283^\circ < l < 293^\circ$ and $2^\circ 5' < b < 10^\circ$. Because of its vertical elongation to the galactic plane, the clouds are named *the Carina flare*. H I and far-infrared emission show a cavity-like distribution corresponding to the molecular clouds, and soft X-ray emission appears to fill this cavity. It is shown that *the Carina flare* represents a supershell at a distance of a few kpc that has been produced by about 20 supernova explosions, or equivalent stellar winds of OB stars, over the last $\sim 2 \times 10^7$ yr. The supershell consisting of molecular and atomic neutral gas involves a total mass and kinetic energy of $\gtrsim 3 \times 10^5 M_\odot$ and $\gtrsim 3 \times 10^{50}$ erg, respectively, and the originally injected energy required is about 100-times this current kinetic energy in the shell. It is unique among supershells known previously because of the following aspects: i) it exhibits evidence for the *triggered* formation of intermediate-to-high-mass stars and massive molecular clouds of $10^2 - 10^4 M_\odot$, and ii) the massive molecular clouds formed are located unusually far above the galactic plane at $z \sim$

100 – 500 pc.

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Distribution and Kinematics of the Molecular Clouds in the Gum Nebula

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We have made an extensive search for molecular gas toward the Gum Nebula in the $J = 1-0$ ^{12}CO emission at 2.6 mm. The ^{12}CO distribution has been used to identify 82 molecular clouds at $|b| > 5^\circ$, including those toward optically visible cometary globules which are likely to be associated with the nebula. Their velocity is significantly deviated from the galactic rotation and the velocity dispersion is as large as $\sim 20 \text{ km s}^{-1}$, indicating that they are expanding under the dynamical effects of OB stars and/or supernova explosions. The total mass of these molecular clouds is estimated to be $\sim 1.7 \times 10^4 M_\odot$, corresponding to $\sim 10\%$ of the HI gas associated with the nebula. Most of these molecular clouds are well explained as part of a supershell of $\sim 70-130 \text{ pc}$ radius that is expanding at $10-15 \text{ km s}^{-1}$. The total kinetic energy of this shell will require a total energy deposit of $\sim (2.1-4.7) \times 10^{50} \text{ erg}$ as the stellar winds and/or the supernova explosions. The massive stars in this region are quantitatively examined as candidates that have supplied this energy.

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A Study of Dense Molecular Gas and Star Formation toward the Vela Molecular Ridge with NANTEN

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New observations of the $J = 1-0$ ^{12}CO , ^{13}CO , and C^{18}O emission lines have been extensively made toward the Vela Molecular Ridge (VMR) with NANTEN. The most prominent cloud is the giant molecular cloud, corresponding to the VMR-C region (Vela C). The present C^{18}O distribution has been identified as 29 clouds. Among them, the most massive one is included in Vela C, having a total mass of $\sim 4.4 \times 10^4 M_\odot$. The rest of them are smaller C^{18}O clouds of $10^2-10^3 M_\odot$. Star formation in the region is almost exclusively occurring in the C^{18}O clouds. The luminosities of the associated protostellar IRAS sources range from $5 L_\odot$ to $1.1 \times 10^4 L_\odot$, and the luminosity distribution is found to be well represented by the relation $dN_{\text{star}}/dL_{\text{IR}} \propto L_{\text{IR}}^{-1.65 \pm 0.14}$. We find that the ratios of the total luminosity of the sources associated with given C^{18}O clouds to the cloud masses are significantly enhanced for those clouds associated with H II regions by an order of magnitude. This is interpreted as meaning that the formation of massive stars is enhanced due to the effects of H II regions, as is consistent with the preceding work. We have also newly found molecular outflow toward IRAS 08588–4347 as well as five possible candidates for outflows.

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Molecular Clouds and Star Formation in the Southern H II regions

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We have carried out extensive $^{13}\text{CO}(J = 1-0)$ observations toward 23 southern H II regions associated with bright-rimmed clouds. In total, 95 molecular clouds have been identified to be associated with the H II regions. Among the 95, 57 clouds are found to be associated with 204 IRAS point sources which are candidates for young stellar objects. There is a significant increase of star-formation efficiency on the side facing to the H II regions; the luminosity-to-mass ratio, defined as the ratio of the stellar luminosity to the molecular cloud mass, is higher by an order of magnitude on the near side of the H II regions than that on the far side. This indicates that molecular gas facing to the H II regions is more actively forming massive stars whose luminosity is $\gtrsim 10^3 L_{\odot}$. In addition, the number density of the IRAS point sources increases by a factor of 2 on the near side of the H II regions compared with on the far side. These results strongly suggest that the active formation of massive stars on the near side of the H II regions is due to the effects of the H II regions, such as the compression of molecular material by the ionization/shock fronts. For the whole Galaxy, we estimate that the present star-formation rate under such effects is at least $0.2-0.4 M_{\odot} \text{ yr}^{-1}$, corresponding to a few 10% by mass.

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A Study of the Molecular Cloud toward the H II Regions S35 and S37 with NANTEN

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We have made new observations of a large field of ~ 10 square degrees toward the two southern H II regions S35 and S37. Observations were made in the ^{12}CO , ^{13}CO , and $\text{C}^{18}\text{O } J=1-0$ emission with the NANTEN telescope at Las Campanas, Chile. These observations have revealed a giant molecular cloud of $\sim 1.3 \times 10^5 M_{\odot}$ in ^{12}CO , highly elongated with a size of $\sim 80 \text{ pc} \times \sim 20 \text{ pc}$, where a previously known active site of star formations, including GGD 27 IRS and HH 80/81, is located. The cloud appears lifted up to $z \sim 100 \text{ pc}$ from the galactic plane at an inclination angle of $\sim 70^{\circ}$, exhibiting indications of strong interactions with the H II regions. Star formation has been found to be very active in the cloud. We have discovered four molecular outflows driven by luminous far-infrared sources of $\sim 10^2 - 10^4 L_{\odot}$ in addition to that previously known toward GGD 27 IRS. The activity is also demonstrated by the existence of several dense C^{18}O clumps whose mass ranges from $\sim 3 \times 10^2 M_{\odot}$ to $\sim 4 \times 10^3 M_{\odot}$. The five molecular outflows are embedded in these C^{18}O clumps. In addition, a comparison with HI shows that the CO cloud is located at the edge of an HI hole of $\sim 55 \text{ pc}$ radius. Since the HI gas surrounding the hole shows a signature of expansion at several km s^{-1} , we suggest that the HI hole represents a supershell created by some explosive events, like supernova explosions, during the last $\sim 4 \times 10^6 \text{ yr}$. This supershell may also provide an explanation for the origin of the molecular distribution.

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Search for Molecular Clouds toward Intermediate-to-High Latitude IRAS Sources in the Southern Sky

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We have conducted a search for molecular clouds toward southern IRAS point sources at intermediate-to-high galactic latitude ($|b| \geq 10^{\circ}$) in $^{12}\text{CO}(J = 1-0)$ emission with the NANTEN telescope. The main purpose of the survey was to find a new sample of star-forming clouds unknown to date. Of the 29 targets, we detected CO emission toward 5 IRAS sources, i.e., 04591-0856, 05044-0325, 05050-0614, 06345-3023, and 13543-3941. Among 5 detections, the molecular cloud associated with 06345-3023 (G239.2-16.3) was detected for the first time. If we assume the distance as being 1.5 kpc, this source is $\sim 430 \text{ pc}$ away from the galactic plane. Three sources 04591-0856 (G208.3-28.4), 05044-0325 (G203.5-24.7), and 05050-0614 (G206.4-25.9) are located west to the Orion molecular clouds, and

13543–3941 (G316.4+21.2) is located in the cometary globule CG 12. Four of the 5 clouds show a cometary shape with a “head-tail” distribution, and three of them have the IRAS source located at the edge opposite to the tail. We find that all of the CO clouds are associated with the optical nebulosities, which are likely to be reflection nebulae. A comparison of the present CO clouds with those in Ophiuchus, Taurus, Chamaeleon, and L1333 indicates that star-forming clouds tend to have a high column density, as well as a smaller ratio of the virial mass to the LTE mass.

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A Dark-Cloud Complex in Aquila: Small Molecular Clouds Possibly Associated with the Aquila Rift

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A $^{12}\text{CO}(J = 1-0)$ survey for local molecular clouds was performed toward dark clouds in Aquila ($26^\circ < l \leq 42^\circ$ and $-25^\circ \leq b < -2^\circ$) by using the 4-meter millimeter wave telescope, NANTEN, at Las Campanas Observatory, Chile. A cloud complex consisting of 64 small clouds has been discovered in $-25^\circ \lesssim b \lesssim -12^\circ$; at a distance of 220 pc, its height from the galactic plane is $\sim 50 - 100$ pc and the total mass is $\sim 4 \times 10^3 M_\odot$. The spatial and velocity distributions of the complex suggest that it may be connected to the Great Rift in Aquila. This complex, as a whole, has a significantly large virial mass compared with the mass derived from the CO intensities by an order of magnitude, though H I gas of $\sim 10^4 M_\odot$, possibly associated, may contribute to bind them gravitationally. The individual CO clouds have velocity dispersion and mass similar to those of the high-latitude clouds; also, the clouds are not in gravitational equilibrium. There is no indication of active star formation.

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Dense Cores and Star-Formation Activities in the Chamaeleon Dark- Cloud Complex

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We carried out a $\text{C}^{18}\text{O}(J = 1-0)$ survey for dense molecular cores in the Chamaeleon (Cha) I, II, and III dark clouds with the NANTEN millimeter-wave telescope. The present survey covered $\sim 93\%$ of the area where the molecular column density is greater than $\sim 4 \times 10^{21} \text{ cm}^{-2}$, estimated from preceding $^{13}\text{CO}(J = 1-0)$ observations. We identified 23 C^{18}O cores, whose typical mass, radius, peak column density, line width are $22 M_\odot$, 0.22 pc, $9.7 \times 10^{21} \text{ cm}^{-2}$, and 0.82 km s^{-1} , respectively. The surface density of classical T Tauri stars abruptly increases for the area whose column density is greater than 10^{22} cm^{-2} , suggesting that this value gives a certain threshold value for star formation. The star-formation efficiency varies over a wide range among the three clouds: 13%, 1%, and 0% in Cha I, II, and III, respectively. The C^{18}O cores in Cha I are characterized by (1) a high column density, (2) being almost in virial equilibrium, and (3) a high $M_{\text{core}}/M_{\text{cloud}}$ ratio. The cores in Cha III show the opposite trend, and those in Cha II are in between. Such trends suggest that Cha I is a well-evolved or well gravitationally relaxed cloud–core system, which is probably related to the very high star-formation activity in the cloud.

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NANTEN Observations of the Pipe Nebula; A Filamentary Massive Dark Cloud with Very Low Star-Formation Activity

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We present molecular line observations toward the “Pipe Nebula” in the $J = 1-0$ lines of ^{12}CO , ^{13}CO , and C^{18}O by using “NANTEN” telescope. An area of $\sim 27 \text{ deg}^2$ was covered at a $4'$ grid spacing with a $2.7'$ beam in ^{12}CO . The ^{12}CO velocity-integrated intensity map and channel maps show a filamentary distribution. The total mass of the ^{12}CO - and ^{13}CO -emitting gas is estimated to be $\sim 10000 M_{\odot}$ and $\sim 3000 M_{\odot}$, respectively. We have identified 14 C^{18}O cores whose mass is typically $\sim 30 M_{\odot}$. Star formation is active only in the B59 region. This activity is best demonstrated by a newly detected CO outflow toward the center of B59. We suggest that the dynamical effects of τ Sco may be responsible for triggering star formation only in the B59 region. The C^{18}O column density toward B59 is extremely high compared with the rest of the cloud. This confirms that high C^{18}O column density is a necessary condition of star formation as previously suggested. Although the star-formation efficiency is estimated to be quite low, $\lesssim 0.1\%$, except for B59, the existence of the C^{18}O cores suggests that there is molecular gas that is massive and dense enough to form stars, and that star formation is likely to occur in the near future.

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NANTEN Observations of the Southern Coalsack in ^{13}CO and $\text{C}^{18}\text{O } J = 1-0$ Emission

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We made observations of the ^{13}CO and $\text{C}^{18}\text{O } J = 1-0$ emission toward the Southern Coalsack. The ^{13}CO observations covered the whole extent of the main cloud with a $2.7'$ beam at an $8'$ or $4'$ grid spacing. The ^{13}CO emitting gas is highly clumpy, consisting of small “cloudlets” of $\leq 0.4 \text{ pc}$ diameter. The densest and most massive cloudlet, whose mass is $\sim 200 M_{\odot}$, is coincident with the region of the heaviest visual extinction, located at the western edge of the cloud. The total mass of the ^{13}CO emitting gas amounts to $\sim 600 M_{\odot}$, corresponding to only $\sim 17\%$ of the total cloud mass estimated from ^{12}CO observations. In addition, toward the densest region in ^{13}CO we made $\text{C}^{18}\text{O } J = 1-0$ observations. We found five C^{18}O dense cores, in agreement with well-known optically dark globules, and identified these dense cores to be potential sites of star formation, as indicated by their high column density, which is typical of star-forming cores. On the other hand, a comparison of the ^{13}CO and C^{18}O distributions with young stellar objects detected as IRAS point sources indicates no sign of recent star formation in the Southern Coalsack.

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A Study of Dense Cloud Cores and Star Formation in Lupus: $\text{C}^{18}\text{O } J = 1-0$ Observations with NANTEN

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We have made an extensive study of dense cloud cores and star formation in the Lupus dark-cloud complex. Millimeter-wave observations in the $\text{C}^{18}\text{O } (J = 1-0)$ emission at 2.6 mm wavelength were made with the “NANTEN”, a 4-m mm-wave telescope of Nagoya University at Las Campanas Observatory. Thirty-six dense cores were identified and

mapped in the C¹⁸O emission at 2' grid spacing with a 2'7 beam. The typical mass, radius, H₂ column density, and line width of the C¹⁸O cores are 9.7 M_⊙, 0.17 pc, 4.1 × 10²¹ cm⁻², 0.90 km s⁻¹, respectively. The mass spectrum of the C¹⁸O cores was fitted by a single power-law index of $\gamma = -1.7 \pm 0.6$ for $M_{\text{core}} \geq 3 M_{\odot}$. The physical parameters of the dense C¹⁸O cores were derived and compared with those in Taurus, Ophiuchus North, and L 1333. The average characteristics of the C¹⁸O cores in Lupus are similar to those in Ophiuchus North and L 1333, although those in Taurus are found to be different, especially in the line width, virial ratio, and mass spectrum index among the four regions. By comparing the physical properties of the C¹⁸O cores with the distribution of YSOs and H¹³CO⁺ condensations in Lupus, we have confirmed a trend suggested in previous studies, that star formation preferentially occurs in cores having a small virial ratio, $M_{\text{vir}}/M_{\text{core}}$, and a large H₂ column density.

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NANTEN Observations of Dense Cores in the Corona Australis Molecular Cloud

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We carried out a C¹⁸O survey for dense molecular cores in the Corona Australis (CrA) molecular cloud with the NANTEN telescope. We observed 2.2 deg² at a 2' grid spacing with a 2'7 beam, and 1980 positions were observed. We identified 8 C¹⁸O cores, whose typical line width, average column density, radius, mass, and average number density were 0.66 km s⁻¹, 1.1 × 10²² cm⁻², 0.13 pc, 18 M_⊙, and 1.4 × 10⁴ cm⁻³, respectively. We found that ΔV_{comp} , $\langle N(\text{H}_2) \rangle$, R , M , and $n(\text{H}_2)$ become larger along with an increase in the star-formation activity, whereas the ratio M_{vir}/M becomes smaller. A comparison of the present cores with those in Chamaeleon, Lupus, Ophiuchus, Taurus, and L1333 indicates that star-forming cores tend to have a high column density, as well as a smaller M_{vir}/M ratio.

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A New Derivation of the Extinction-to-CO Column Density Ratio in the Chamaeleon I Dark Cloud

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We have analyzed new datasets of ¹³CO($J = 1-0$) and C¹⁸O($J = 1-0$) emission obtained with NANTEN and visual extinction, A_V , derived from DENIS J -band observations in the Chamaeleon I dark cloud. The column densities of both molecular isotopes, $N(^{13}\text{CO})$ and $N(\text{C}^{18}\text{O})$, have been derived assuming LTE. Both $N(^{13}\text{CO})$ and $N(\text{C}^{18}\text{O})$ are linearly correlated with A_V in the range $A_V \lesssim 10$ mag. We established the relationships $N(^{13}\text{CO})(\text{cm}^{-2}) = (1.2 \pm 0.1) \times 10^{15} A_V(\text{mag}) + (0.7 \pm 0.3) \times 10^{15}$ and $N(\text{C}^{18}\text{O})(\text{cm}^{-2}) = (3.5 \pm 0.3) \times 10^{14} A_V(\text{mag}) - (5.7 \pm 1.3) \times 10^{14}$. In a region of clustered T Tauri stars, however, both the $A_V-N(^{13}\text{CO})$ and $A_V-N(\text{C}^{18}\text{O})$ relationships are by a factor of ~ 2 steeper than the above. This may be mainly due to underestimates of the A_V values, and the J -band star count might deserve a more careful examination for possible underestimates of associated young stars. Compared with the relationships for the other clouds, the slope of the $A_V-N(^{13}\text{CO})$ relationship is relatively shallower and that of the $A_V-N(\text{C}^{18}\text{O})$ relationship in a non-cluster forming region is slightly steeper. These facts suggest that cloud-to-cloud variation is significant in the $A_V-N(\text{CO})$ relationships.

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Dissertation Abstracts

Evolutionary models of rotating low mass stars

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Ph.D degree awarded: November 1999

We have investigated the combined effects of rotation and internal angular momentum redistribution on the structure and evolution of low mass stars, from the pre-main sequence to the main sequence phase. As a tool for that study, the ATON stellar evolutionary code (Mazzitelli 1989; Ventura et al. 1998) has been modified in order to include those effects. Rotation was implemented according to the equipotential technique developed by Kippenhahn & Thomas (1970) and later improved by Endal & Sofia (1976). Angular momentum redistribution in radiative regions was modeled through an advection-diffusion partial differential equation based on the framework originally introduced by Chaboyer & Zahn (1992), which is based on the sole assumption of stronger turbulent transport in the horizontal direction than in the vertical one. The diffusion coefficient of this equation is obtained from characteristic lengths and velocities of typical rotation-induced hydrodynamical instabilities. This improved code was used to compute a series of rotating low mass stellar models (with masses ranging from $1.2 M_{\odot}$ down to $0.6 M_{\odot}$). Regarding the structural (hydrostatic) effects of rotation, the general features of these models show that rotating stars behave as if they were non-rotating stars of slightly lower masses, in accordance with previous results by other researchers. A study of this mass-lowering effect for the considered range of masses shows that rotation decreases lithium depletion while the star is fully convective but *increases* it as soon as the star develops a radiative core. The net effect is an enhanced lithium depletion, in disagreement with observational data which suggest that faster rotators in young open clusters experience less lithium depletion. Angular momentum redistribution in the considered models is very effective in smoothing their internal angular velocity profile as soon as the star reaches the zero age main sequence, but fails to reproduce the flat solar rotation rate obtained from helioseismology, indicating that, in the Sun, angular momentum transport is more efficient than current models. The internal angular momentum transport also contributes to a still higher lithium depletion than the models computed with only the structural effects of rotation, thus suggesting that other physical phenomena must play a role regarding both lithium depletion and the rotation profile evolution of these stars.

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Class II Methanol Masers at High Resolution

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Ph.D degree awarded: November 1998

Observations of the 6.7- and 12.2-GHz masing transitions of methanol by Norris *et al.* (1998, *Nature*, 335, 149; 1993, *ApJ*, 412, 222) using the Australia Telescope Compact Array (ATCA) and the Parkes-Tidbinbilla Interferometer (PTI) found that for ten of the seventeen sources imaged the individual maser components had a linear spatial distribution. Many of the linear sources also had a velocity gradient along the source. This is in marked contrast to similar observations of OH and H₂O masers. Norris *et al.* interpreted this to be evidence of an edge-on circumstellar disc surrounding a young massive star.

The evolution of young massive stars is poorly understood, because the stars are surrounded by a cocoon of dust and dense molecular gas. Thus the direct detection of a disc around these stars would be a major step in understanding the dynamics of the formation of massive stars. In this thesis I have taken a sample of methanol sources and observed them using a variety of instruments and techniques to improve our understanding of these interesting objects and find further evidence to investigate the circumstellar disc model of linear methanol maser sources.

The sources imaged by Norris *et al.* were some of the brightest known methanol masers. In this thesis, I have used the ATCA to imaged a further ten methanol sources which have a more modest flux. All the methanol sources originally observed by Norris *et al.* have been reobserved either in this thesis or by Ellingsen *et al.* (1996, *MNRAS*, 279, 101). As many of the maser sources have separate sites of emission separated by a few arcseconds to a few arcminutes, there are 45 maser sources which have now been observed at high resolution using the ATCA. Seventeen of these sources have a linear morphology. No difference in the properties of the linear and non-linear sources could be found.

Simultaneous observations of the 8.6 GHz continuum towards the methanol sources have been made for all the sources in the sample. Half of the methanol sources are associated with an ultra-compact HII (UCHII) region. The sources without UCHII regions may either be pre-main sequence, or are associated with a less massive embedded star.

The Anglo-Australian Telescope has been used to observe the 11.5 μ m continuum emission associated with 35 of the maser sources. Nine of the sources were found to have detectable mid-infrared (MIR) emission. No correlation has been found between the methanol and MIR luminosities. The observations were sensitive enough to detect embedded stars of spectral type B3 and above. That so few sources were found to have a MIR counterpart indicates that there are large variations in the circumstellar environment of the methanol sources.

A VLBI proper motion study at 6.7 and 12.2 GHz of a subsample of eight of the linear sources has been started using the Australian VLBI network. If the lines do represent edge-on circumstellar discs then it should be possible to detect Keplerian rotation in 3 to 5 years.

The ATCA has been used to search for extragalactic 6.7-GHz methanol “megamasers” towards 87 galaxies selected on their *IRAS* colours and known OH megamaser galaxies. No methanol emission was found, with a typically detection limit of 15-40 mJy. This is surprising given the close association between Galactic OH and methanol masers.

<http://www.nfra.nl/~phillips/thesis.html>

New Jobs

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The Department of Physics and Astronomy at University of California Los Angeles (<http://www.astro.ucla.edu>) invites applications for a postdoctoral research position in adaptive optics. The successful applicant will join Prof. Andrea Ghez's effort on star formation and/or galactic center research in the new NSF Science & Technology for Adaptive Optics in Astronomy and Vision Science. This work will be carried out primarily at the W. M. Keck 10-m and Lick 3-m telescopes.

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by Feb. 15, 2000.

For further information contact Bruce Runnegar, Director, UCLA Center for Astrobiology (runnegar@ucla.edu), Ben Zuckerman (ben@astro.ucla.edu), or Andrea Ghez (ghez@astro.ucla.edu). UCLA is an affirmative action/equal opportunity employer; women and members of minorities are especially encouraged to apply for these positions.

Meetings

REMINDER

3rd “Three-Island” Euroconference on Clusters and Associations

Cargese (Corsica, France), Apr. 3-8, 2000

From Darkness to Light: Origin and Early Evolution of Stellar Clusters

The web page of the Conference can be found at: http://www.phys.ens.fr/cargese/euroconf_clusters

Deadline for pre-registration, abstract submission, and financial help:

Jan. 31, 2000

Contact: montmerle@cea.fr

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