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From the Editor

I am presently moving from ESO to a position at the Observatoire de Grenoble in France, and on the way I spend half a year at institutes in Brazil, Denmark and USA. All my e-mail will be forwarded to wherever I am at any given time, so you can continue to send your abstracts to the usual e-mail address at ESO. The only difference is that, at least for the next two months, you will not receive an acknowledgement of receipt when you submit an abstract. In December I will provide the e-mail address in Grenoble to be used henceforth.

Bo Reipurth

Abstracts of recently accepted papers

The Classical T Tauri Spectroscopic Binary DQ Tau. II. Emission Line Variations with Orbital Phase

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We report on echelle observations of a variety of line profiles taken throughoutthe orbit of the close, eccentric binary T Tauri system DQ Tau. The stars themselves exhibit puzzling inconsistencies in the spectral types inferred from atomic vs. molecular lines. The system shows clear evidence of an extensive circumbinary disk. The binary is expected to clear a central hole in the disk, however the line profiles are similar to those from single classical T Tauri stars. This indicates that similar infall and outflow activities are taking place. The implication is that material is flowing through the supposed gap in the disk. It also means that these "classical" profiles do not require a stable circumstellar disk for their formation, since the stellar separation at periastron is too small to allow such disks.

We present evidence that accretion increases (sometimes dramatically) as the stars approach each other. Both continuum veiling and emission line intensitiescan increase. In one outburst the Ca II IR lines brighten by a factor of 5. Wediscuss the line profiles during such outbursts in some detail. Along with increased accretion, the lines sometimes also imply high velocity outflows. Given the fact that outbursts can occur as much as 0.15 in phase away from closest approach, we favor accretion over direct magnetospheric interactions as the power source of the outbursts. Away from each other, the stars resemble moderate- to low-activity classical T Tauri stars. There is evidence that some material is stored near the stars and ingested throughout the orbit. These observations are generally consistent with a model for disks in binary systems proposed by Artymowicz and Lubow (1996). The importance of this system is that it provides empirical support for continuing accretion through dynamical tidal gaps in disks. It demonstrates that very close binaries can be classical T Tauri systems.

Accepted by Astron. J.

Preprints are available by anonymous ftp from soleil.berkeley.edu ("cd pub" then get dq*.ps).

Giant Planet Formation by Gravitational Instability

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The recent discoveries of extrasolar giant planets, coupled with refined models of the compositions of Jupiter and Saturn, prompt a re-examination of theories of giant planet formation. An alternative to the favored core accretion hypothesis is examined here, gravitational instability in the outer solar nebula leading to giant planet formation. Three dimensional hydrodynamical calculations of protoplanetary disks show that giant gaseous protoplanets can form with locally isothermal or adiabatic disk thermodynamics. Gravitational instability appears to be capable of forming giant planets with modest cores of ice and rock faster than the core accretion mechanism.

Accepted by Science

17μm molecular hydrogen line emission from OMC–1

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The v=0–0 S(1) line of molecular hydrogen at 17.03 μm has been measured in the source OMC–1 along a 90″ cut passing through the near–IR H_2 emission Peaks 1 and 2 using the Kuiper Airborne Observatory. The line flux is typically 50% of the 2.12 μm v=1–0 S(1) line, but its distribution is somewhat more extended and it is relatively brighter at Peak 2. We interpret this as shocked emission coming from two regions of roughly equal brightness and lying close to the plane of the sky, plus a more extended contribution from slower shocks ($\sim 5\,\mathrm{km\,s^{-1}}$) which do not contribute significantly to the near–IR vibrational-rotational lines. The 17 μm line flux is an order of magnitude too strong to be explained by planar J– and C–shock models. However our data cannot distinguish between the merits of a cooling flow dominated by H_2 line emission and the integrated emission from a C–type bow-shock. Both models predict column density ratios close to those observed from a variety of lines covering a range from 1 000 to 25 000 K in upper state energy. We predict a flux for the ground state 28.2 μm 0–0 S(0) line of $\sim 2\%$ that of the 1–0 S(1) line at Peak 1, and suggest that a consistent set of observations of the lowest pure rotational lines of H_2 would allow us to distinguish between these shock models.

Accepted by Astronomy and Astropysics

High resolution observations of molecular outflows in the HH 1–2 region

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We report ^{12}CO J = 3–2 high resolution observations of compact molecular outflows around VLA 1 and VLA 3, two young stellar objects in the HH 1–2 region. We have confirmed the existence of a new outflow associated with VLA 1, the powering source of these well known Herbig-Haro objects. The VLA 1 outflow exhibits red- and blue-shifted peaks with a separation of only 30″. The two lobes are clearly distinct from each other, suggesting that the outflow axis is close to the plane of the sky. The outflow is aligned with the HH 1–2 axis, but the lobes are inside the HH knots. Our calculations have shown that this outflow is one of the weakest, youngest and most compact ever seen. Its total mass is 1.1×10^{-3} $M_\odot$ and the dynamical timescale is $\simeq 1\times10^3$ years. We have also mapped the more extended outflow from VLA 3 confirming the existence of two young, distinct and! very compact molecular outflows in this region.

Accepted by Astronomy & Astrophysics (Letters)

Preprint available on the WWW at http://www-star.qmw.ac.uk/∼jcc/pub.html

High-resolution spectroscopy of Vega-like stars - II: Age indicators, activity, and circumstellar gas

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We have completed a high-resolution optical study of 14 stars classified as Vega-like, having an IR excess attributable to dust emission.

Surface lithium abundances were measured for the four G- and K- type stars of the sample, to test the suggestion that these Vega-like stars are intermediate in evolutionary state between pre-main sequence objects and established main sequence stars. Abundances ranged from a very high value in the G5e star HD 143006, implying a youthful age of only 1 Myr, to below the limit of measurement for the K2V star HD 23362, which we conclude to be already well established on the main sequence.

The emission line characteristics of all the stars in our sample were studied to compare with those seen in the classical pre-main sequence Herbig Ae/Be stars and T Tauri stars. Activity levels ranged from stars showing little or no activity, such as HD 23362, to those exhibiting extensive activity such as the A9/F0Ve star HD 144432, which showed distinctive P Cygni profiles in its spectrum, and HD 143006, which is young enough to be included in the T Tauri class of stars. The A2/3e star HD 35187 shows evidence of variability in its Hα and He I λ5876 lines, with four other A-type stars in our sample also showing evidence of He I λ5876 activity in the form of emission or absorption. We interpret the excess absorption and/or emission in the λ5876 line as providing direct evidence for ongoing accretion activity on these systems. We find that the emission characteristics of the Hα, Na I D, He I and Ca II K lines are not significantly different from those of Herbig Ae/Be stars and T Tauri stars. Some of our sample have also been previously classified as pre-main sequence or candidate pre-main sequence stars, which would seem to suggest that there is no distinct boundary between Vega-like stars and the Herbig Ae/Be and T Tauri stars. The surface gravities of the A- and F- type stars in our sample imply that they have already reached the main sequence, consistent with the short timescales to reach the main sequence predicted for stars of their mass and the fact that they are not located close to star formation regions. On the other hand, the ages derived for the three emission-line G- and K- type stars in our sample imply that they have probably not yet reached the main sequence. It is likely that these emission-line Vega-like stars represent the intermediate stage between classical pre-main sequence stars with "dusty" IR excesses and stars which are well established on the main sequence.

We also studied our sample for evidence of optical circumstellar gas absorption features. Of the fourteen stars, seven show evidence for narrow absorption lines in their spectra. Most of these appear to be of interstellar origin. One of these stars, HD 144432, has a narrow absorption component in the absorption trough of its Na I D P Cygni profile, at a heliocentric velocity of –91 kms^{-1}, which excludes an interstellar origin and therefore more likely originates in its circumstellar environment. We also detect narrow absorption lines in the spectrum of HD 158643 (51 Oph) arising from excited state Fe II lines, which can only come from the circumstellar environment of the star.

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On the widespread Weak-Line T-Tauri population detected in the ROSAT All-Sky Survey

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We discuss the apparent widespread presence of Weak-Line T-Tauri stars (WTTS) among stellar coronal sources detected in the ROSAT All-Sky Survey (RASS), and their relative number with respect to young main-sequence stars in the same samples. The approach taken in most of the current literature for identifying and classifying WTT stars among RASS X-ray sources is based on the usage of low-resolution optical spectra only and on simple, mass-

independent thresholds on the equivalent width of the Li I 6707.8 Å doublet. We show that this approach is likely to lead to putative WTTS samples which contain a large number of normal, young main-sequence stars masquerading as WTTS sources. Young main-sequence stars are known to be the dominant contributor in stellar X-ray selected samples at the limiting flux levels of the RASS, yet they appear to be very rare in the RASS samples discussed here. We argue that many of the putative WTTS sources are actually mis-classified young main-sequence stars, and that thus there is likely not a true "WTTS question" in the RASS samples.

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A deflected molecular jet in the bipolar outflow NGC 2264G

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Recently published H_2 emission data for the bipolar molecular outflow NGC 2264G are compared to recent CO $(2 \rightarrow 1)$ observations and existing VLA images. Virtually all of the H_2 emission associated with this outflow is found either behind clumps of swept-up ambient material (i.e. closer to the central source of the outflow) or along the axis of the highest velocity CO emission. The highest velocity CO features appear to arise in jets that emerge from H_2 emission knots and generally follow a pattern consistent with a deflection of a jet at these points. These deflections appear to result in part from a temporal change in the direction of the bipolar axis of the outflowing material ejected from the central source. We propose that effects such as these play a role in degrading the collimation of jet driven outflow lobes.

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http://astro.uwaterloo.ca/ fich/publications.html

Injection of Radioactive Nuclides from the Stellar Source that Triggered the Collapse of the Presolar Nebula

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We examine the gravitational capture of supersonic gas and dust as it impacts and triggers the collapse of a molecular cloud core. We use two techniques to track the triggering material in two dimensions, a set of tracer particles and a color field, much like a dye, computed in the same manner as the hydrodynamic density variable. The two tracking techniques produce very similar results. We find that about 10% to 20% of the supersonic material with an initial impact parameter less than the molecular cloud core's initial radius is captured by the collapsing cloud. This fraction is less than the 100% capture estimate often used to constrain the distance to possible stellar sources of radioactive isotopes, and hence may require these stars to be closer than would otherwise be the case. Rayleigh-Taylor instabilities occur and aid in the mixing of the shock material with the target cloud. The impacting material is injected into the outer layers of the collapsing protostar roughly one free fall time (2×10^5 yrs) after the first contact of the triggering material with the cloud, and injection continues for approximately two more free fall times. These time intervals are substantially less than the mean life of one of the radioactive nuclides of interest, 1.1×10^6 yrs for ^{26}Al, and are comparable to the mean life (1.5×10^5 yrs) of another short-lived nuclide, ^{41}Ca. Evidence for live ^{26}Al and ^{41}Ca in the early solar system is thus consistent with a scenario involving supersonic triggering and injection of freshly synthesized radioactive nuclides into the presolar cloud. Because injection proceeds at a steady pace, it does not appear to be a significant source of temporal heterogeneity in the distribution of ^{26}Al, though the outer layers of the presolar cloud are preferentially enriched in the injected material.

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A Survey of Optical and Near-Infrared Jets in Taurus Embedded Sources

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We describe optical ([S II], 6732 Å) and near-infrared (H_2, 2.122 μm) imaging observations of 21 embedded protostars in the Taurus-Auriga molecular cloud. Our survey identifies 4 new [S II] emission sources and 4 new H_2 sources. We detect three emission knots in both [S II] and H_2; one object with H_2 emission has no [S II] emission. These results increase the number of class I sources with optical or near-IR outflows to 13. We also detect [S II] emission in two additional class II sources, ZZ Tau IRS and IC 2087 IRS. When combined with previous results, the frequency of optical outflows among class II sources, $\sim 10\%$, is much smaller than the frequency among class I sources, $\geq 60\%$. The large difference in the frequency of optical and molecular outflows indicates that outflow activity decreases with age among pre-main sequence stars.

The jets in the Taurus-Auriga protostars are poorly collimated, with multiple knots indicative of large opening angles, $\sim 10°$–$40°$. The image morphologies are complex and suggest a time dependence in the direction of ejection. A simple precessing jet can account for the sinusoidal chain of [S II] knots – HH 31 – associated with 04248+2612. The precessing jets, together with the good alignment between the axes of the jets, molecular outflows, and reflection nebulae, support current models where jets produce molecular outflows and bipolar cavities in the dense infalling cloud cores surrounding class I sources.

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Time Dependent Accretion by Magnetic Young Stellar Objects as a Launching Mechanism for Stellar Jets

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A time-dependent jet launching and collimating mechanism is presented. Initial results of numerical simulations of the interaction between an aligned dipole rotator and a conducting circumstellar accretion disk which is initially threaded by the dipole field show that differential rotation between the disk and the star leads to the rapid expansion of the magnetic loops that connect the star to the disk. The expansion of these magnetic loops above and below the disk produces a two-component outflow. A hot, well collimated outflow is generated by convergent flow of attached plasma towards the rotation axis, while a cool, slower outflow is produced on the disk side of the expanding loop. The expanding loop, which later forms a plasmoid, defines the boundary between the jet-like flow and the disk wind. Episodic magnetic reconnection above and below the disk releases the jet plasma from the system and allows the process to repeat, reinforcing the hot, well collimated outflow.

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Tracing the envelopes around embedded low-mass young stellar objects with HCO^+ and millimeter-continuum observations

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The envelopes and disks around embedded low-mass young stellar objects (YSOs) are investigated through millimeter

continuum and HCO^+ line emission. Nine sources, selected on the basis of their HCO^+ 3–2 emission from an IRAS flux- and color-limited sample of 24 objects, are observed in $\lambda = 3.4$ and 2.7 mm continuum emission with the Owens Valley Millimeter Array, and in the HCO^+ and $H^{13}CO^+$ 4–3, 3–2, and 1–0 transitions at the James Clerk Maxwell and IRAM 30m telescopes. All nine sources are detected at 3.4 and 2.7 mm in the interferometer beam, with total fluxes between 4 and 200 mJy. The visibilities can be fit with an unresolved ($< 3''$) point source, and, in about half of the sources, with an extended envelope. The point sources, presumably thermal dust emission from circumstellar disks, typically contribute 30–75% of the continuum flux observed at 1.1 mm in a $19''$ beam, assuming a spectral slope of 2.5. The fact that at least two-thirds of our sources show point-source emission indicates that circumstellar disks are established early in the embedded phase. The remainder of the 1.1 mm single dish flux is attributed to an extended envelope, with a mass of 0.001–0.26 $M_\odot$ within a $19''$ beam. In HCO^+, the J=1–0 line is seen to trace the surrounding cloud, while the emission from J=3–2 and 4–3 is concentrated toward the sources. All sources look marginally resolved in these lines, indicative of a power-law brightness distribution. A beam-averaged HCO^+ abundance of $(1.2 \pm 0.4) \times 10^{-8}$ with respect to H_2 is derived.

The 1.1 mm continuum fluxes and HCO^+ line intensities of the envelopes correlate well, and are modeled with the simple inside-out collapse model of Shu (1977) and with power-law density distributions of slopes $p = 1$–3. All models provide satisfactory fits to the observations, indicating that HCO^+ is an excellent tracer of the envelopes. Of the 15 sources of the original sample that were either undetected in HCO^+ 3–2 or too weak to be selected, seven show 1.1 mm single-dish fluxes comparable to our objects. It is proposed that all of the 1.1 mm flux of the former sources should be attributed to compact circumstellar disks. The relative evolutionary phase of a YSO, defined as the current ratio of stellar mass over envelope mass, is traced by the quantity $\int T_{\rm mb} dV (\mathrm{HCO^+}\ 3{-}2) \,/\, L_{\rm bol}$. Sources which are undetected in HCO^+ are found to to have significantly lower values in this tracer than do the objects of our subsample, indicating that the former objects are more evolved. The sources which are weak in HCO^+ 3–2 are indistinguishable from our subsample in this tracer, and have intrinsically low masses. It is concluded that HCO^+, especially in its 3–2 and 4–3 transitions, is a sensitive tracer of the early embedded phase of star formation.

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http://www.strw.leidenuniv.nl/∼michiel/preprints.html

Rotation Periods for Stars in NGC 2264

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Four fields in the young cluster NGC 2264 were monitored in Cousins I with a CCD on the 0.6 m telescope at Van Vleck Observatory during the 1995/96 observing season. A total of 209 stars were followed, reaching a limiting magnitude of about 16. Nine periodic variables were found and they are interpreted as spotted, pre-main sequence stars with rotation periods ranging from 1.2 to 9.7 days. Three additional possible spotted variables, one with a period of only 0.71 days, and one possible eclipsing binary were also found. Comparing with the Orion Nebula Cluster (ONC), we find that there is a higher proportion of rapid rotators in NGC 2264 among stars with detected periods. Since the ONC sample is probably younger, this may be evidence for spin-up of most pre-main sequence stars as they contract towards the main sequence. If this interpretation is correct, it suggests that disk braking may not be important for most stars beyond an age of ~ 1 million years.

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Preprints are available from $http://hea-www.harvard.edu/QEDT/kristin/ngc2264_AJ97.html$

Infrared Search for Young Stars in HI High-velocity Clouds

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We have searched the IRAS Point Source Catalog and HIRES maps for young stellar objects (YSOs) in the direction of five HI high-velocity clouds (HVCs). In agreement with optical searches in the halo, no evidence was found for extensive star-forming activity inside the high-latitude HVCs. Specifically, we have found no signs of star formation or YSOs in the direction of the A IV cloud or in the very-high-velocity clouds HVC 110-7-465 and HVC 114-10-440. We have identified only one young star in the direction of the M I.1 cloud, which shows almost perfect alignment with a knot of HI emission. Because of the small number of early-type stars observed in the halo, the probability for such a positional coincidence is low; thus, this young star appears to be physically associated with the M I.1 cloud. We have also identified a good YSO candidate in the HI shell-like structure observed in the core region of the low-latitude cloud complex H (HVC 131+1-200). This region could be a supernova remnant with several other YSO candidates formed along the shock front produced by the explosion.

In agreement with recent theoretical estimates, these results point to a low but significant star-formation rate in intermediate and high Galactic latitude HVCs. For M I.1 in particular, we estimate that the efficiency of the star-formation process is $M(\mathrm{YSO})/M(\mathrm{HI}) \gtrsim 10^{-4}-10^{-3}$ by mass. Such efficiency is sufficient to account for (a) the existence of the few young blue stars whose ages imply that they were born in the Galactic halo, and (b) the nonprimordial metallicities inferred for some HVCs if their metal content proves to be low.

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Physical Properties of Molecular Cloud Cores in L1630 and Implications for Star Formation

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We present the results of a multitransition, CS study of massive dense cores in the L1630 molecular cloud with spatial resolutions ranging from 11 – 64″. The primary goal of this investigation is to determine whether the physical properties of massive cores are related to their star formation efficiency (SFE) and, in particular, their ability to form rich embedded clusters. The spatial and density structure of 4 massive cores and 2 low mass cores in this cloud were examined. Densities for each core were determined through an LVG analysis. We find that all the massive cores contain regions with densities of at least 10^5 cm^{-3}. In general, cores with rich embedded clusters, and consequently with high SFE, tend to be larger (i.e., to have larger areas of detectable CS J=5→4 emission) than those without clusters and low SFE. In addition, the region emitting CS J=5→4 emission has a lower volume filling factor of gas denser than 10^5 cm^{-3} in high SFE cores than in low SFE cores. These differences suggest that regions forming rich embedded clusters have larger amounts of dense gas, and they are more fragmented.

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The tidal disruption of protoplanetary accretion discs

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In this paper we revisit the problem of the tidal interaction occuring between a protostellar accretion disc and a secondary point mass following a parabolic trajectory. We model the disc response analytically and we compare our results with three-dimensional SPH simulations.

Inviscid as well as viscous hydrodynamics is considered. We show that in a viscous system the response derived from inviscid considerations is predominant even for the highest estimates of an anomalous disc shear viscosity. The angular momentum lost from the disc during the encounter is derived from linear theory, for distant fly-bys, as well as the changes to the disc orientation expected in non-coplanar encounters.

It is shown that the target discs can become warped and precess by a small amount during non-coplanar encounters. This small precession is shown to give rise to a relative tilt of the disc which is always more important for determining its final orientation than is the change to the orbital inclination.

We discuss the implications of our results for protostellar accretion discs and planetary systems.

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PostScript files available from: http://www.maths.qmw.ac.uk/∼jdl/

Submillimetre photometry of protostellar cores in Bok globules

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JCMT submillimetre continuum observations at 450 and 800 μm are presented for ten dense cores in Bok globules, and observations at 350 and 1100 μm are presented for three of the cores. The data are combined with IRAS data at 12–100 μm and IRAM data at 1.3 mm, and the spectral energy distributions of the cores are compiled. The mean temperature of the cold dust in the cores is estimated from greybody fits to be $T_{\rm d} = 23 \pm 3$ K. Typical gas masses of cores which are forming single or binary stars are ∼0.2–2.5 $M_\odot$. Cores which are forming clusters have higher masses in the range ∼3–35 $M_\odot$. The beam-averaged Hydrogen column and volume densities are all derived to be in the ranges $\sim 10^{22}$–10^{23} cm^{-2} and $\sim 10^5$–10^6 cm^{-3} respectively. We confirm that CB 244 VLA 1 is a Class 0 protostar, and hypothesize that CB 17 is a pre-stellar core.

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Millimetre dust emission from northern Bok globules

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We present the results of a 1.3 mm continuum study of 59 Bok globules located north of −30° declination. The catalogue of Clemens & Barvainis (1988) served as a search list for the target objects investigated here. Based on the analysis of the IRAS point source colour-colour diagram, four distinct groups of globules are distinguished. It is shown that indeed each of these groups has distinctive properties and represents a different stage of star-formation. For our observations, we selected a number of candidate pre-protostellar cores, all candidates for globules with protostellar cores, as well as a number of strong 12 μm IRAS point sources which are candidates for T Tauri stars associated with globules.

Individual distances of the globules are derived with a method which associates the globules with larger molecular cloud complexes. It is shown that most globules are associated with such cloud complexes from which they probably formed. The derived distances range from 140 pc to 2 kpc with the majority of the globules being related to Gould's Belt at distances of 200 to 300 pc. The average distance of our sample of globules is derived to be 500 pc.

Out of the 59 globule cores observed at 1.3 mm, 21 objects were detected with average 3 σ detection limits of 17 mJy/12″ and 39 mJy/23″. This corresponds to an overall detection rate of 35%. While most of the detected objects are protostellar cores, four pre-protostellar cores and one T Tauri star were detected furthermore. The typical mass of a star formed in a Bok globule is derived to be $\approx 0.5\,M_\odot$. Using the detection rates and the relative frequencies of the globule groups, lifetimes of the different evolutionary stages are derived. Assuming that all globules form stars at some time of their evolution, the typical lifetime of a Bok globule is derived to be some 10^6 years. It is speculated that the existence of isolated T Tauri stars can be explained by star formation in Bok globules. In addition, the results of the continuum measurements are compared with observations of different molecular lines.

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Looking for Distributed Star Formation in L1630: A Near-infrared (J, H, K) Survey

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We have carried out a simultaneous, multi-band (J, H, K) survey over an area of 1320 arcmin^2 in the L1630 region, concentrating on the region away from the dense molecular cores and with modest visual extinctions ($\leq$ 10 mag). Previous studies found that star formation in L1630 occurs mainly in four localized clusters, which in turn are associated with the four most massive molecular cores (Lada et al. 1991; Lada 1992). The goal of this study is to look for a distributed population of pre-main-sequence stars in the outlying areas outside the known star-forming cores. More than 60% of the pre-main-sequence stars in the active star forming regions of NGC 2024 and NGC 2023 show a near-infrared excess in the color-color diagram. In the outlying areas of L1630, excluding the known star forming regions, we found that among 510 infrared sources with the near-infrared colors (($J - H$) and ($H - K$)) determined and photometric uncertainty at K better than 0.10 mag, the fraction of the sources with a near-infrared excess is 3%–8%; the surface density of the sources with a near-infrared excess is less than half of that found in the distributed population in L1641, and 1/20 of that in the young cluster NGC 2023. This extremely low fraction and low surface density of sources with a near-infrared excess strongly indicates that recent star formation activity has been very low in the outlying region of L1630. The sources without a near-infrared excess could be either background/foreground field stars, or associated with the cloud, but formed a long time ago (more than 2 Myrs). Our results are consistent with McKee's model of photoionization-regulated star formation.

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Preprint: `http://bubba.as.utexas.edu/wenbin`

MHD Simulations of Stellar Magnetosphere - Accretion Disk Interaction

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The magnetohydrodynamical evolution of the interaction region between the inner edge of an accretion disk and the magnetosphere of the central object is studied by means of time-dependent numerical simulations. The simulations assume the disk is adiabatic, axisymmetric, has non-zero resistivity, and is initially in Keplerian rotation. The magnetosphere is assumed to be initially in magnetostatic equilibrium, corotating with the central star, and threaded by one of three different initial magnetic field topologies: 1) a pure dipole field which also threads the disk continuously everywhere, 2) a dipole field excluded from the disk by surface currents, and 3) a dipole field continuously threading a disk superposed with a uniform axial magnetic field. A number of exploratory simulations are performed by varying the field strength, the disk density and inner radius, the magnitude of the resistivity, and the stellar rotation rate. These simulations are designed as an initial study of the magnetohydrodynamics of the interaction region.

Generally, we find rapid evolution of the disk occurs due to angular momentum transport by either the Balbus-Hawley instability or magnetic braking effects. Equatorial accretion results on a dynamical timescale unless the magnetic pressure of the magnetosphere exceeds the ram pressure of the accreting disk plasma; the latter we find to be a highly time dependent quantity. In the case of a pure dipole magnetospheric field, however, rapid stellar rotation can result in a field geometry which inhibits polar accretion even when ram and magnetic pressures balance. In contrast, we find that polar accretion can occur regardless of the stellar rotation rate when strong global disk magnetic fields combine with stellar magnetic fields to create a favorable net field topology.

Highly time dependent winds are evident in the evolution of all three field topologies. The winds are generally channeled along field lines which have been opened due to reconnection. The speed and variability of the outflows is dependent on the magnetic field strength and accretion topology. Net torque on the star during accretion is measured to be positive, i.e., the star is being spun up.

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Discovery of Jets and HH-like Objects Near the S255 IR Complex

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We report the discovery of two jets and eight HH-like objects in molecular hydrogen near the Sharpless HII region S255, and present near-infrared observations of these objects. The field has been imaged in [FeII] (1.644 μm), cK (2.26 μm), H_2 v= 1→0 S(1), and H_2 v= 2→1 S(1) as well as in broad-band JHK$'$ filters, as part of an ongoing near-infrared survey of massive star-forming regions. These observations reveal in detail the morphology of low and intermediate-velocity shocks in the region. The HH-like objects are seen only in H_2. The brightest H_2 clump is found to the SW of the S255 IR complex. We see evidence of one possible counter jet: a faint H_2 tail to the NE of S255 IR seen as a series of clumps. Their arc-shaped geometry is indicative of bow-shocks. Diffuse emission is also seen in S255 IR, toward the North and South. K-band long slit spectroscopy suggests a collisional nature for the brightest H_2 object, rather than fluorescence. These observations also indicate that the Brγ excess present in S255 IR may be produced by the stellar wind of the very red star NIRS 1 while the H_2 diffuse emission may come from collisionally-shocked gas present in the extended nebulosity of the region. We also present the results of ^{12}CO (J= 1→0) observations of the region. We find two foci of accelerated molecular gas which suggests the presence of two molecular outflows, one associated with the ultracompact HII region G192.58-0.04, and the other with the S255 IR region and one of the jets.

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ROSAT detection of Class I protostars in the CrA Coronet

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We analyze archival ROSAT data of the CrA star forming region. X-ray emission from five infrared Class I protostars in the Coronet cluster was recently found in ASCA data, however, with low spatial resolution and partly ambiguous source identification. ROSAT high spatial resolution data confirm the X-ray detection of three Class I protostars. The other two infrared protostars might be extincted to strongly for being detected in the softer ROSAT bandpass. Alternatively, the X-ray emission might be strongly variable and they might have been too faint in X-rays at the time of the ROSAT observations.

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Pre-prints available from Ralph Neuhäuser at rne@mpe-garching.mpg.de

IRAS 12553–7651 in Chamaeleon II: A low mass PMS Star with a C^{18}O Outflow?

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We present new multi-line, multi-isotope observations of the PMS candidate IRAS 12553–7651 in the nearby Chamaeleon II dark cloud. Previous far infrared and molecular observations towards three selected objects in Cha II determined that IRAS 12553–7651 was the most likely candidate to be a young (proto)stellar object. We thus mapped the IRAS 12553–7651 region in the ^{12}CO $J = 2 \rightarrow 1$, ^{13}CO $J = 2 \rightarrow 1$, and C^{18}O $J = 1 \rightarrow 0$ rotational transitions to use probes more sensitive to higher density gas and not affected by optical depth effects. We also observed and detected

the $C^{34}S$ $J = 2 \rightarrow 1$ transition. Our observations confirm the presence of a high-density clump at the position of the IRAS source with $V_{LSR} \simeq 3$ km s^{-1}, and reveal a $C^{18}O$ *velocity shift* aligned along an axis SW–NE, of about 2 km s^{-1} pc^{-1}, which is likely to be an outflow. Based upon this assumption, the ^{13}CO spectra of Olmi et al. (1994) have been re-analyzed and found to show a deviation from a Gaussian shape. This asymmetry can be interpreted in terms of a line component which migrates in velocity with respect to the ambient cloud. We show that a model in which the bipolar outflow interacts with the ambient gas around IRAS 12553–7651 may reproduce qualitatively the observational data.

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Self-Similar Magnetocentrifugal Disk Winds with Cylindrical Asymptotics

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We construct a two-parameter family of models for self-collimated, radially self-similar magnetized outflows from accretion disks. A flow at zero initial poloidal speed leaves the surface of a rotating disk and is accelerated and redirected toward the pole by helical magnetic fields threading the disk. At large distances from the disk, the flow streamlines asymptote to wrap around the surfaces of nested cylinders. In constrast to previous disk wind modeling, we have explicitly implemented the cylindrical asymptotic boundary condition to examine the consequences for flow dynamics. The solutions are characterized by the logarithmic gradient of the magnetic field strength and the ratios between the footpoint radius R_0 and asymptotic radius R_1 of streamlines; the Alfven radius must be found as an eigenvalue. Cylindrical solutions require the magnetic field to drop less steeply than 1/R. We find that the asymptotic poloidal speed on any streamline is typically just a few tenths of the Kepler speed at the corresponding disk footpoint. The asymptotic toroidal Alfven speed is, however, a few times the footpoint Kepler speed. We discuss the implications of the models for interpretations of observed optical jets and molecular outflows from young stellar systems. We suggest that the difficulty of achieving strong collimation in vector velocity simultaneously with a final speed comparable to the disk rotation rate argues against isolated jets and in favor of models with broader winds.

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Full text and figures available as Postscript file at:

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Sub-arcsec resolution infrared images of the star forming region G 35.20–1.74

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We present J(1.25 μm), H(1.65 μm), K(2.2 μm), H_2(2.125 μm) and 11.2 μm infrared images at sub-arcsec resolution of an area centered around the star forming region G 35.20–1.74. In J, H and K a cluster of early type stellar sources with infrared excess clearly stands out with respect to the background distribution and is associated with a diffuse K emission around an UC HII region (which is the brightest source at K). No H_2 emission is detected in narrow–band images at 2.125 μm.

At 11.2 μm six components are detected. The brightest one (MIR3) is extended and coincides with the UC HII region. The source with steepest IR spectrum and the largest infrared excess (MIR1) is associated with an H_2O maser and a near IR source detected only at K. It is separated from the IR cluster and at a distance of 20″ from the UC HII region. The IR emission comes from a local young stellar object (YSO) associated with the maser. The lack of radio continuum emission from MIR1 confirms that H_2O masers can trace the youngest evolutionary stages of massive YSOs,

much before the appearance of a radio UC HII region and shows that star formation is not limited to the IR cluster (where most probably it has already come to an end) but is still taking place in other parts of the molecular cloud. Of the other 11.2 μm sources, three (MIR2, MIR4 and MIR5) present IR excesses and are similar to MIR1, while MIR6 appears to be a reddened early-type star.

The morphology of the entire star forming complex, taking into account also molecular and sub-mm observations, is indicative of different and independent episodes of star formation taking place in the same molecular cloud.

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http://www.arcetri.astro.it/ testi/preprints.html

Hopkins Ultraviolet Telescope Observations of H_2 Emission from HH2

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The Hopkins Ultraviolet Telescope spectrum of HH2 shows Lyman band emission below 1200 Å, and it reveals H_2 bands in the quasi-continuum at longer wavelengths. The H_2 emission could arise either from Lyα fluorescence (as in other HH objects) or collisional excitation by hot electrons. The fluorescence hypothesis encounters some difficulty in explaining the lack of individual strong features, while the collisional hypothesis must explain the mixing of hot electrons into the molecular gas before photoionization or collisions with H atoms dissociate the molecules. The spectrum also provides a stringent upper limit to the O VI flux. The upper limit appears to conflict badly with the predictions of bow shocks models which match the observed line widths of HH2A' and HH2H.

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A Molecular Line and Infrared Study of NGC 2264 IRS1

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We present a study of the region around the intermediate–mass young stellar object NGC 2264 IRS1. This source is embedded in a dense cloud core. Infrared images in the J, H, and K band show a jet–like structure connected with IRS1 as well as a second very deeply embedded small star cluster to the southeastern side. IRS1 itself is surrounded by a number of embedded low–mass stars. We mapped this area in various CS transitions, CO 3→2, some methanol lines and in $C^{18}O$ 2→1. The mapping results clearly show a second cloud clump centered at the small star cluster. Two molecular outflows were found in the observed region. One flow is oriented along our line of sight and associated with IRS1 and the other flow is centered at the small star cluster.

Several additional spectral line settings were taken at the IRS1 position to get more accurate constraints on the gas temperature and density. These data, as well as the maps, were analysed with statistical equilibrium excitation calculations. The best fit results give an uniform temperature of about 55 K in a quite large inner cloud region ($1' \times 1'$), with even warmer gas (>70 K) present close to IRS1 and the embedded star cluster. This warm cloud core is surrounded by extended material at a temperature of 20 to 30 K. Radiative transfer models applied for different molecules constrain the mean central density to 2 10^6 cm^{-3}.

We estimated the beam-averaged total H_2 column densities at a number of grid positions around IRS1 from the $C^{18}O$ measurements. Using the modeled CS excitation, we can constrain the beam-averaged CS abundance distribution over the same area. The inferred CS abundance with respect to H_2 of 1 10^{-9} is nearly constant over the whole region, and there is no indication for a CS depletion on this scale.

Observations of a large number of other molecules have been obtained as well at the IRS1 position. The resulting abundances are compared to those found in other high– and low–mass young stellar objects. The abundances of the

organic molecules H_2CO and CH_3OH are somewhat enhanced, whereas those of sulfur–bearing molecules are much lower. The most striking characteristic of the NGC 2264 chemistry is its nitrogen chemistry, especially the very high abundances of N_2H^+ and N_2. These results suggest that NGC 2264 is in a somewhat later evolutionary stage.

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Hipparcos data on Herbig Ae/Be stars: an evolutionary scenario

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Fundamental astrophysical parameters (distance, temperature, luminosity, mass, age) of a sample of 10 Herbig Ae/Be candidates and 3 non-emission line A and B stars in star forming regions were computed combining Hipparcos parallaxes with data from literature. All genuine Herbig stars in our sample are located between the birthline and the zero-age main sequence (ZAMS) in the Hertzsprung-Russell diagram (HRD), in accordance with what is expected for pre-main sequence stars. The region in the HRD close to the birthline is relatively devoid of stars when compared to the region closer to the ZAMS, in agreement with the expected evolutionary time scales. The Herbig Ae/Be stars not associated with star forming regions were found to be located close to the ZAMS. Additionally we discuss a possible evolutionary scenario for the circumstellar environment of Herbig stars.

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A preprint of this paper is available via the WWW at http://www.astro.uva.nl/preprints/preprints.html

Studies of Ultracompact HII Regions - I. Methanol Maser Survey of IRAS Selected Sources

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A survey of ultracompact (UC) HII regions has been carried out by searching for 6.669GHz methanol maser emission from a sample of 535 IRAS selected candidates. A total of 201 candidates exhibit methanol emission. These sources have been used, in conjunction with previously identified UC HII regions, to provide a base for further studies of such regions. Estimates of distances have indicated that the identified UC HII regions tend to have some Galactic structure but it is not clear whether they lie in or between the spiral arms of the Galaxy. The regions are tightly constrained to the plane of the Galaxy. Comparison of identified regions and IRAS sources selected by Wood & Churchwell (1988) indicate there there is some degree of contamination, which could be due to an older phase in the life on an UC HII region where methanol maser emission is not apparent. Luminosities and spectral types have been derived for many of the regions. The maximum number of maser spots observed seems to increase with increasing peak maser luminosity which indicates that the maser emission is more dependent on the abundance of methanol than the availability of FIR radiation.

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Near Infrared Polarimetric Study of Mon R2 IRS

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We present H and K_s band imaging polarimetry for the star forming region Mon R2 IRS, and spectropolarimetry from 1.2 to 4.2 μm for the infrared sources IRS 2 and IRS 3. The nebular complex in Mon R2 IRS is revealed as four domains dominated by the infrared sources IRS 1, IRS 2, IRS 3 and IRS 6. IRS 2 is the predominant illuminating source in the region and dominates the emission of the IR ring and most of the western part of the nebulosity. IRS 1 is responsible for the enhanced unpolarized intensity of the SE part of the IR ring and inside the IR ring. IRS 3 illuminates the bright eastern nebula and illuminates the eastern region inside the IR ring together with IRS 2. IRS 6 illuminates a small nebula to the south of the IR ring. An arc structure of polarized intensity is observed abutting the NW IR ring, consistent with the outflow cavity structure inferred from mm-wave observations. IRS 3 is associated with a disk-like condensation oriented in the SE-NW direction, perpendicular to the elongated eastern nebula. The magnetic field in the core region exhibits an hour-glass structure oriented along the N-S direction.

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Shock-Excited H_2 Flows in OMC-2 and OMC-3

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We report the discovery of nearly a dozen collimated outflows from young stellar objects embedded in the molecular filament that extends north of the Orion Nebula towards the H II region NGC 1977. The large number of nearly co-eval outflows and embedded class-0 young stellar objects indicates that the OMC-2/3 region is one of the most active sites of on-going low to intermediate mass star formation known. These outflows were identified in the 2.12 μm v = 1–0 $S(1)$ H_2 line during a survey of a 6 arcmin × 16 arcmin region containing the OMC-2 and OMC-3 cloud cores and over a dozen recently discovered class-0 protostars. We also observe filamentary emission that is likely to trace possible fluorescent H_2 in photo-dissociation regions associated with M 43 and NGC 1977. Neither the suspected outflows nor the fluorescent emission are seen at the continuum wavelength of 2.14 μm which confirms their emission line nature. Several of the new H_2 flows are associated with recently discovered bipolar molecular outflows. However, the most prominent bipolar CO outflow from the region (the MMS 8 flow) has no clear H_2 counterpart. Several H_2 flows consist of chains of knots and compact bow shocks that likely trace highly collimated protostellar jets. Our discovery of more than 80 individual H_2 emitting shocks demonstrate that outflows from young stars are churning this molecular cloud.

Accepted by ApJ Letters

http://casa.colorado.edu/ kachun/research/omc2-3/

Dynamical Collapse in W51 Massive Cores: NH_3 Observations

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We present high angular resolution (0.2″ – 1″, ∼ 1600AU – 8000AU) studies of the W51 HII region complex in the NH_3 (J,K)=(1,1), (2,2) and (3,3) inversion transitions. This region has been identified previously with spectroscopic signatures of gravitational collapse (Ho & Young 1996). In one of the infalling cores W51e2, we detect radial infall of about 3.5 km s^{-1} at scales of ∼ 1″ (0.04 pc) from the star. The inward motion in the core is nearly constant. A

velocity gradient of about 4 km s^{-1} exists at scales $< 0.4''$. The velocity gradient which maximizes in the east-west direction, increases inward in radius as $r^{-1.2}$, indicating rotation and spin-up of material during the course of collapse. The infall and rotational motions are comparable in the inner core close to the star.

The molecular gas across both the e2 and e8 infall regions is hot (40-50K) and dense ($> 10^6$ cm^{-3}). The NH_3 rotational temperature remains roughly constant throughout the collapsing region. The mass densities in the infall region increase inward and scale with radius as r^{-2}. This density distribution and the total mass in the infall zones are consistent with free falls of constant speed at different spatial scales.

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