Abstracts of recently accepted papers

Theoretical Models of Young Open Star Clusters: Effects of a Gaseous Component and Gas Removal

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We construct a family of semi-analytic models for young open clusters, including a gaseous component and varying assumptions about the distribution function for the stellar component. The parameters of these models are informed by observed open clusters and general theoretical considerations regarding cluster formation. We use this framework to estimate the fraction $\mathcal{F}$ of the stellar component that remains gravitationally bound after the gaseous component disperses. The remaining stellar fraction $\mathcal{F}$ is a smooth function of the star formation efficiency ϵ_*, and depends on the distribution function of the stars. We calculate the function $\mathcal{F}(\epsilon_*)$ for this class of open cluster models and provide fitting formulae for representative cases.

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Infrared Interferometric Observations of Young Stellar Objects

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We present infrared observations of four young stellar objects using the Palomar Testbed Interferometer (PTI). For three of the sources, T Tau, MWC 147 and SU Aur, the 2.2 μm emission is resolved at PTI's nominal fringe spacing of 4 milliarcsec (mas), while the emission region of AB Aur is over-resolved on this scale. We fit the observations with simple circumstellar material distributions and compare our data to the predictions of accretion disk models inferred from spectral energy distributions. We find that the infrared emission region is tenths of AU in size for T Tau and SU Aur and ~1 AU for MWC 147.

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Dense Cores and Molecular Outflows in the OMC-2/3 Region

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We have observed the OMC-2/3 region in the $H^{13}CO^+(1-0)$, $HCO^+(1-0)$, and $CO(1-0)$ lines by using the Nobeyama 45 m radio telescope. We have identified eighteen dense cores in $H^{13}CO^+$ and eight molecular outflows in CO and HCO^+ in OMC-2/3. Four of these outflows are newly found. The linewidths of the $H^{13}CO^+$ cores in OMC-2/3 are twice as large as those in dark clouds, and the momentum fluxes ($\dot{P}_{flow} = P_{flow}/\tau_D = \dot{M}_{flow}V_{flow}$) of the outflows in OMC-2/3 are approximately 2 orders of magnitude larger than those of outflows in dark clouds. We found that the mass loss rate of the outflow is proportional to the third power of the core velocity dispersion, which suggests that the outflow mass-loss rate is proportional to the mass infall rate onto the protostar. From a comparison between the properties of cores associated with protostars and those without protostars, we suggest that the dissipation of turbulence initiates star formation.

HST/STIS spectroscopy of the optical outflow from DG Tau: structure and kinematics on sub-arcsecond scales

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We have carried out a spatio-kinematic study of the outflow from the classical T Tauri star DG Tau using the *Space Telescope Imaging Spectrograph* (STIS) on board the Hubble Space Telescope (HST). A series of seven spatially offset long-slit spectra spaced by $0.07''$ were obtained along the axis of the outflow to build up a 3-D intensity-velocity "cube" in various forbidden emission lines (FELs) and $H\alpha$. Here we present high spatial resolution synthetic line images close to the star in distinct radial velocity intervals (from $\sim +50\,\mathrm{km\,s^{-1}}$ to $\sim$ -450 $\mathrm{km\,s^{-1}}$ in four bins, each $\sim 125\,\mathrm{km\,s^{-1}}$ wide). The lowest velocity emission is also examined in finer detail (from $+60\,\mathrm{km\,s^{-1}}$ to -70 $\mathrm{km\,s^{-1}}$ in five bins $\sim 25\,\mathrm{km\,s^{-1}}$ wide). We have found that the highest velocity and most highly collimated component, i.e. the jet, can be traced from DG Tau to a distance D$\sim 0.7''$. The jet is on the axis of a pear-shaped limb-brightened bubble which extends between $0.4''$ and $1.5''$ from the source and which we interpret as a bow shock. Other condensations are seen close to the star indicating ongoing temporal variations in the flow. The low-velocity component of the outflow is found to be spatially wide close to the source ($\sim 0.2''$ at D=$0.2''$), in contrast to the high velocity jet (width $\leq 0.1''$). We have also found evidence to suggest that not only does the density in the outflow increase longitudinally with proximity to the source but that it also increases laterally towards the flow axis. Thus, at least in the case of DG Tau, the flow becomes gradually denser as it increases in velocity and becomes more collimated. Our observations show a continous bracketing of the higher speed central flow within the lower speed, less collimated, broader flow, down to the lowest velocity scales. This suggests that the low and high velocity FELs in the highly active T Tauri star DG Tau are intimately related. Implications of these observations for FEL models will be considered in a future paper (Bacciotti et al. 2000).

NLTE calculations of neutral helium lines in the wind of the Herbig Ae star AB Aur

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In order to improve our knowledge about the structure of the winds of the Herbig Ae/Be stars and the mechanisms

that drive them, we performed a NLTE analysis of the formation of helium lines in the wind of AB Aur, the prototype of the whole class. These lines are indeed expected to form in the densest layers of the envelope, at the very base of the wind, and therefore to provide constraints on these regions where the wind originates. A large observational data set is now available which we have extensively used to deduce strong constraints on the physics that prevail in the inner part of the wind. Among these data, we particularly used those from the MUSICOS 1996 campaign, which show that the He I D3 ($\lambda 5876$ Å) line is made of two distincts components: a blue-shifted emission component, and a redshifted component alternatively seen as an absorption or an emission.

The classical model for AB Aur's wind (Bouret & Catala 1998, Catala & Kunasz 1987) fails to reproduce the observed profile. We find that the observations can be explained by a two component model in which the base of the wind includes dense and hot clumps of outflowing material, while the bulk of the wind is still described by the model by Bouret & Catala (1998). This clumpy structure can result from the presence of co-rotating interaction regions which form where fast streams in the wind overtake slow streams. Our results show that a blue-shifted emission is formed in such conditions, and can be rotationally modulated as observed, due to fast and slow streams alternating on the line of sight as the star rotates.

Our model can also explain the occasional presence of an absorption component near rest wavelength, as formed in the bulk of the extended chromosphere. Concerning the red emission component, which is occasionally observed instead of the absorption one, we argue that it may arise from polar downflows.

The radial distribution of OB star formation in the Galaxy

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We present the azimuthally averaged radial distribution of 748 regions of OB star formation in the whole galactic disk, based on our previous CS(2-1) survey of UC H II regions. Embedded massive stars produce a total FIR luminosity of $1.39\,10^8\,L_\odot$ within the range $0.2 \leq R/R_\circ \leq 2$ in galactocentric radius. We find 492 massive star forming regions within the solar circle, producing 81% of the total FIR luminosity. Separate analyses of the 349 sources in the I and II quadrant (north), and of the 399 sources in the III and IV quadrant (south), yield FIR luminosities (extrapolated to the complete galactic disk) of $1.17\,10^8\,L_\odot$ and of $1.60\,10^8\,L_\odot$, respectively. Massive star formation is distributed in a layer with its centroid $Z_\circ(R)$ following that of molecular gas for all galactocentric radii, both north and south. Its thickness for $R \leq R_\circ$ is ~ 73 pc (FWHM), 62% the thickness of the molecular gas disk. The FIR luminosity produced by massive stars has a well defined maximum at $R = 0.55\,R_\circ$, with a gaussian FWHM of $0.28\,R_\circ$ - compared with $0.51\,R_\circ$ for the H_2 surface density distribution. Toward the outer Galaxy, down from the maximum, the face-on FIR surface luminosity decays exponentially with a scale length of $0.21\,R_\circ$, compared with $0.34\,R_\circ$ for the H_2 surface density. Massive star formation per unit H_2 mass is maximum for $R \sim 0.55\,R_\circ$ in the southern Galaxy, with a FIR surface luminosity to H_2 surface density ratio of $\sim 0.41\,L_\odot/M_\odot$, compared with $\sim 0.21\,L_\odot/M_\odot$ at the same radius in the north, and with an average of $\sim 0.18\,L_\odot/M_\odot$ for the whole galactic disk within the solar circle.

Turbulent Molecular Cloud Cores: Rotational Properties

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The rotational properties of numerical models of centrally condensed, turbulent molecular cloud cores with velocity

fields that are characterized by Gaussian random fields are investigated. It is shown that the observed line width – size relationship can be reproduced if the velocity power spectrum is a power-law with $P(k) \propto k^n$ and $n = -3$ to -4. The line-of-sight velocity maps of these cores show velocity gradients that can be interpreted as rotation. For $n = -4$, the deduced values of angular velocity $\Omega = 1.6$ km s^{-1} pc$^{-1} \times$ (R/0.1 pc)$^{-0.5}$ and the scaling relations between Ω and the core radius R are in very good agreement with the observations. As a result of the dominance of long wavelength modes, the cores also have a net specific angular momentum with an average value of $J/M = 7 \times 10^{20} \times$ (R/0.1 pc)$^{1.5}$ cm^2 s^{-1} with a large spread. Their internal dimensionless rotational parameter is $\beta \approx 0.03$, independent of the scale radius R. In general, the line-of-sight velocity gradient of an individual turbulent core does not provide a good estimate of its internal specific angular momentum. We find however that the distribution of the specific angular momenta of a large sample of cores which are described by the same power spectrum can be determined very accurately from the distribution of their line-of-sight velocity gradients Ω using the simple formula $j = p\Omega R^2$ where p depends on the density distribution of the core and has to be determined from a Monte-Carlo study. Our results show that for centrally condensed cores the intrinsic angular momentum is overestimated by a factor of 2-3 if $p = 0.4$ is used.

High Resolution Imaging of Photodissociation Regions in NGC 6334

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We have used the SPIREX telescope to conduct a wide-field thermal infrared imaging study of the star formation complex NGC 6334 in the southern galactic plane. We imaged a 30$'$ region along the main star forming ridge of NGC 6334 with 0.6$''$ pixel scale through broad-band filters for L (3.5μm) and M (4.8μm), and through narrow-band filters in the H$_2$ v=1–0 Q–branch (2.42μm), PAH (3.3μm) and Br α (4.05μm) lines. The images reveal the spectacular, complex structure of the photodissociation regions (PDRs) that pervade the region, with enhanced line emission around each of the seven sites of massive star formation along the ridge. Bubbles and loops of PAH emission, typically 1–1.5 pc across, have been carved out of the parent molecular cloud by the intense UV radiation from the massive stars, and surround HII regions (seen in Br α) typically 0.2–0.3 pc across. The PAH emission regions coincide with both [CII] 158μm line emission, indicating the PAHs are excited in PDR gas, and with extensive H$_2$ emission, which therefore must be fluorescent. However the texture of the emission regions in PAH and H$_2$ is different. This is attributable to variations in the physical environment in which the gas is excited. Several compact reddened objects are observed; these are likely to be massive protostars.

The Structure of the Monoceros R2 Molecular Cloud Core

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We present the result of molecular line observations of Mon R2. Maps in lines tracing high density show an arc-like structure surrounding the H II region. Maps of temperature deduced from H_2CO line ratios reveal a hot spot with $T_K > 100$ K coincident with a submillimeter continuum peak. Maps of density deduced from CS line ratios indicate that the density peaks near IRS 1 and declines away from it. The spherically averaged data can be modeled equally well with a power law (with an exponent of 0.8–0.9) or a Gaussian with an FWHM of 1.0 pc. In either case, densities in the central region are around 10^6 cm^{-3}. The derived density gradient suggests that the thermal pressure is not the only source of cloud support, and the relation between the density gradient and the cloud mass suggested from similar studies of other regions also holds in the Mon R2 cloud core.

preprint at http://www.asiaa.sinica.edu.tw/minho/pubs/

OH Zeeman Measurement of the Magnetic Field in the L1544 Core

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We report observations with the Arecibo telescope of the Zeeman effect in the 1665 and 1667 MHz lines of OH toward eight dark cloud cores. For L1544 the inferred line-of-sight magnetic field is $B_{los} = +10.8 \pm 1.7$ μG. The L1544 starless core has been observed to have infall motions; it may be very close to forming a star. $B_{los} \approx 11$ μG is consistent with the prediction of an ambipolar diffusion model computed specifically for this core before the Zeeman measurements were made; however, in order to obtain agreement with the data this model has **B** inclined by only 16° to the plane of the sky. Virial arguments show that unless the magnetic field is mainly in the plane of the sky, it is not important for support of the L1544 core. For L1457S our result is $B_{los} = -24 \pm 7$ μG, a possible but not definite detection. The other six cores were only observed with short integration times, and the Zeeman effect was not detected in these cores.

New, high-resolution, near-infrared observations of HH 1

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We present new, high-resolution, near-infrared images of the HH 1 jet and bow shock. H_2 and [FeII] images are combined to trace excitation changes along the jet and across the many shock features in this flow. Echelle spectra of H_2 profiles towards a few locations in HH 1 are also discussed. Gas excitation in oblique, planar C-type shocks best explains the observations, although J-type shocks must be responsible for the observed [FeII] emission features. Clearly, no single shock model can account for all of the observations. This will probably be true of most, if not all, Herbig-Haro flows.

Preprints available from http://www.jach.hawaii.edu/∼cdavis/papers.html

The stellar content of the compact H II region Sh2-88B

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We present a photometric study of the compact H II region Sh2-88B and its associated stellar cluster. The positions and *JHK* magnitudes are obtained for 125 stars over an $80'' \times 80''$ field centered on the region.

The region has two components, called Sh2-88B1 and Sh2-88B2. B1 is a compact cometary H II region associated with a cluster containing several massive stars. The dominant exciting star, at the center of the cometary structure, has an ionizing radiation flux corresponding to a spectral type in the range O8.5V–O9.5V. It is highly reddened, with a visual extinction in the 30–42 mag range, and exhibits a near-IR excess. B1 has a simple morphology, with the ionized and neutral gas clearly separated. Its unidentified infrared band (UIB) emission, observed by ISOCAM in the 5–8.5 μm passband, comes from the photodissociation region at the periphery of the ionized gas. B2 is an ultracompact H II region whose exciting star, probably of spectral type later than B0.5V, is not detected; this indicates a visual extinction greater than 60 mag. A very steep and regular increase of the extinction from west to east is observed over the whole of Sh2-88B.

Spectroscopy of molecular hydrogen in outflows from young stars

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We present new medium-resolution longslit spectra in the near-infrared and examine the excitation of molecular hydrogen across several outflows from young stars. In contrast to previous studies, in which the brightest patches in the flows were selected, we find evidence for variations in excitation with position within several sources.

We present and comment on a number of H_2 excitation mechanisms of outflows from the literature, and compare them with our observations. H_2 position-velocity diagrams and line ratios support a picture in which the excitation variations are caused by the large-scale shock geometry. The variations are best interpreted by magnetohydrodynamic C-shocks, although some locations which demonstrate hydrodynamic J-type excitation are found. In particular, VLA 1623 is accurately modelled by a C-type bow, whereas a planar J-type model is favoured for HH 57. HH 1/2 consists of a collection of molecular bow and planar shocks. The H_2 emission from the leading edge of the HH 1 bow structure is actually from a low-excitation oblique wing from one of many mini bow shocks rather than from fluorescence or a magnetic precursor.

In two of our objects, the jets themselves are also traced in molecular hydrogen emission. Radial velocities in the infrared jet in HH 47C demonstrate acceleration consistent with the proper motions, and hint at ballistic motions originating in an eruptive event about 280 years ago. In this jet, as well as in the HH 1 infrared jet, we find the excitation to decline with distance from the source.

Chandra X-ray Observatory Study of the Orion Nebula Cluster and BN/KL Region

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About 1000 X-ray emitting young pre-main sequence (PMS) stars distributed in mass from $\sim$0.05 $M_\odot$ brown dwarfs to a $\sim$ 50 $M_\odot$ O star are detected in an image of the Orion Nebula obtained with the Advanced CCD Imaging Spectrometer on board the Chandra X-ray Observatory. This is the richest field of sources ever obtained in X-ray

astronomy. Individual X-ray luminosities in the Orion Nebula Cluster range from the sensitivity limit of $< 2 \times 10^{28}$ erg s^{-1} to $\sim 10^{32}$ erg s^{-1}. ACIS sources include $85 - 90\%$ of $V < 20$ stars, plus a lower but substantial fraction of deeply embedded stars with extinctions as high as $A_V \simeq 60$.

The relationships between X-ray and other PMS stellar properties suggest that X-ray luminosity of lower-mass PMS stars depends more on mass, and possibly stellar rotation, than on bolometric luminosity as widely reported. In a subsample of 17 unabsorbed stars with mass $\simeq 1$ M$_\odot$, X-ray luminosities are constant at a high level around $L_x \simeq 2 \times 10^{30}$ erg s^{-1} for the first $\simeq 2$ My while descending the convective Hayashi track, but diverge during the $2-10$ My phase with X-ray emission plummeting in some stars but remaining high in others. This behavior is consistent with the distribution of X-ray luminosities on the zero-age main sequence and with current theories of their rotational history and magnetic dynamos.

The sources in the Becklin-Neugebauer/Kleinman-Low (BN/KL) region of massive star formation are discussed in detail. They include both unabsorbed and embedded low-mass members of the Orion Nebula Cluster, the luminous infrared Source n, and a class of sources without optical or infrared counterparts that may be new magnetically active embedded PMS stars. Several X-ray sources are also variable radio emitters, an association often seen in magnetically active PMS stars. Faint X-ray emission is seen close to, but apparently not coincident with the Becklin-Neugebauer object. Its nature is not clear.

A Near-Infrared L Band Survey of the Young Embedded Cluster NGC 2024

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We present the results of the first sensitive L band (3.4 μm) imaging study of the nearby young embedded cluster NGC 2024. Two separate surveys of the cluster were acquired in order to obtain a census of the circumstellar disk fraction in the cluster. We detected 257 sources to the m$_L \leq 12.0$ completeness limit of our $\sim$110 arcmin^2 primary survey region. An additional 26 sources with $12.0 < L < 14.0$ were detected in the deeper survey of the central $\sim$6.25 arcmin^2 region of the cluster. From an analysis of the $JHKL$ colors of all sources in our largest area, we find an infrared excess fraction of $\geq 86\% \pm 8\%$. The $JHKL$ colors suggest that the infrared excesses arise in circumstellar disks, indicating that the majority of the sources which formed in the NGC 2024 cluster are currently surrounded by, and likely formed with circumstellar disks. The excess fractions remain very high, within the errors, even at the faintest L magnitudes from our deeper surveys suggesting that disks form around the majority of the stars in very young clusters such as NGC 2024 *independent* of mass. From comparison with published $JHKL$ observations of Taurus, we find the $K - L$ excess fraction in NGC 2024 to be formally higher than in Taurus, although both fractions are quite high. Thus, existing L band observations are consistent with a high initial incidence of circumstellar disks in both NGC 2024 and Taurus. Because NGC 2024 represents a region of much higher stellar density than Taurus, this suggests that disks may form around most of the YSOs in star forming regions *independent* of environment. We find a relatively constant $JHKL$ excess fraction with increasing cluster radius, indicating that the disk fraction is independent of location in the cluster. In contrast, the JHK excess fraction increases rapidly toward the central region of the cluster. The most likely cause for this increase is the contamination of the K band measurements by bright nebulosity in the central regions of the cluster. This suggests that caution must be applied using only JHK band observations to infer disk fractions in nebulous environments. Finally, we identify 45 candidate protostellar sources in the central regions of the cluster, and we find a lower limit on the protostellar phase of early stellar evolution in the NGC 2024 cluster of 0.4 - 1.4 $\times$ 10^5 yr, similar to that in Taurus.

Properties of the Photodissociated Gas in NGC 6334

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In order to investigate the properties of photodissociated gas in strong radiation fields, the massive star formation region NGC 6334 has been mapped with the FIFI instrument in the far-infrared fine-structure transitions [C II] 158 μm, [O I] 146 μm, and [O I] 63 μm. Bright [C II] 158 μm emission is found throughout the cloud, whereas the [O I] 146 μm emission is associated only with the star-forming ridge. Comparison of the relative intensities of the lines with single-component photodissociation region models suggests densities of $n_H \sim 10^4$ cm^{-3}. The models imply unphysically large radiation fields for three sources, particularly for NGC 6334 A, probably due to self-absorption in the [O I] 63 μm line. An alternative method for estimating physical conditions, based on the correlation between [C II] 158 μm and CO line intensities, is explored. This method implies hydrogen column densities of $N_H \geq 10^{22-23}$ cm^{-2}, which agree well with those from molecular excitation models. The relative distribution of the [C II] 158 μm and [O I] 146 μm emission supports clumpy photodissociation region models which suggest the [C II] 158 μm emission arises from interclump gas and thus should be more extended than the [O I] 146 μm emission that arises from the denser clumps. The spatial coincidence of [C II] 158 μm emission peaks with minima in the molecular gas emission indicates that at least some of the molecular holes contain photodissociated gas. The relative pressures of the ionized, photodissociated, and molecular gas are compared: the photodissociated and molecular gas are in approximate pressure equilibrium, but the ionized gas is overpressurized by at least an order of magnitude at the continuum sources.

CO Outflows from Young Stars: Confronting the Jet and Wind Models

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We have mapped the CO J=1-0 emission from molecular outflows associated with five young stellar systems of class 0 to class II/III using the BIMA array and the FCRAO 14-m antenna. The systems, VLA 05487, HH 212, HH 240/241, HH 111, and RNO 91, are all relatively nearby and low luminosity, and the majority have H_2 emission or optical jet features. The CO outflow generally forms a shell structure around the outflow axis with the higher velocity emission further out from the source. Two distinctive kinematic features are evident in position-velocity (PV) diagrams: a parabolic structure originating at the driving source (e.g., VLA 05487 and HH 111) and a convex spur structure with the high velocity tip near known H_2 bow shocks (e.g., HH 212, HH 240/241 and HH 111). The parabolic PV structure can be produced by a wide-angle-wind model, while the velocity spur structure can be modeled with a jet-driven bow shock model. VLA 05487, which is not associated with any H_2 bow shocks, shows only the parabolic structure and kinematics consistent with the wide-angle-wind driven model. HH 212, which is associated with a series of H_2 bow shock structures, shows a striking morphological coincidence between the H_2 and CO emission and velocity spurs in the PV diagram. It is our best example of the jet-driven bow shock model and its kinematics can be qualitatively explained in that context. HH 240/241 is similar to HH 212 and shows a close relationship between the H_2 and CO emission. The kinematics of its western lobe can also be explained with the jet-driven model. The kinematics of RNO 91 are similar to VLA 05487 and are broadly consistent with a wide-angle-wind driven model. HH 111 has both parabolic and spur PV structures, a combination that is not easily explained in the simplest version of either model.

Thus, these observations provide examples of systems which support either the wide-angle-wind driven or jet driven model in the simplest interpretation. More detailed calculations are needed to understand whether one model might be able to fit all systems. It is crucial to know if time-dependent or long-lived jet-driven bow shock models can produce the outflow widths and parabolic PV structures, or if a wide-angle wind can produce the shock features and velocity

spur structures in our observations.

A High Resolution Radio Survey of Class I Protostars

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We report the results of a survey of low mass Class I protostars in the cm continuum. In the initial survey, seven sources in the Taurus star formation were observed with the VLA at $0.25''$ resolution. All seven sources drive CO outflows and display Herbig-Haro flows in the optical or near infrared wavebands. 4/7 sources were detected, two of which are new discoveries in systems of very low luminosity, one being the lowest luminosity system detected to date in the cm continuum. Notably, three sources were not detected to a 3-σ limit of 0.10 mJy/beam, which indicates that significant cm continuum emission is not a universal feature of Class I systems with outflow activity. Subsequent observations of HH30, a more evolved Class II system, found no emission to a 3-σ limit of 0.03 mJy/beam. After comparison with near infrared data, we suggest that the discriminating feature of the detected systems is a relatively high ionisation fraction in the stellar wind. Temporal variability of the outflow may also play a role: only recently ejected knots may have sufficiently dense plasma to be optically thick to free-free emission, and hence produce detectable flux. The one relatively bright source, IRAS 04016+2610 (L1489 IRS), is clearly resolved on a 0.4" scale at 2 cm and 3.5 cm. Follow-up imaging with MERLIN did not detect this source with a 0.04" beam, indicating that the radio emission is generated in a region with a radius of ≈ 25 au, which is broadly similar to the radius of the bipolar cavities inferred from models of near infrared data. Interpretation of this system is complicated by the existence of a quadrupolar outflow, i.e. two bipolar outflows along roughly perpendicular axes, which we originally detected through polarimetric imaging. We present a near infrared H_2 image in which a bow shock in the secondary outflow is clearly seen. This complicated structure may have been caused by a gravitational interaction between two protostars.

The η Chamaeleontis Cluster: Origin in the Sco-Cen OB Association

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A young, nearby compact aggregate of X-ray emitting pre-main sequence stars was recently discovered in the vicinity of η Chamaeleontis (Mamajek, Lawson & Feigelson 1999, ApJ, 516, L77). In this paper, we further investigate this cluster: its membership, its environs and origins. *ROSAT* High-Resolution Imager X-ray data for the cluster's T Tauri stars show high levels of magnetic activity and variability. The cluster has an anomalous X-ray luminosity function compared to other young clusters, deficient in stars with low, but detectable X-ray luminosities. This suggests that many low-mass members have escaped the surveyed core region. Photographic photometry from the USNO-A2.0 catalog indicates that additional, X-ray-quiet members exist in the cluster core region. The components of the eclipsing binary RS Cha, previously modeled in the literature as post-main sequence with discordant ages, are shown to be consistent with being coeval pre-MS stars.

We compute the Galactic motion of the cluster from *Hipparcos* data, and compare it to other young stars and associations in the fourth Galactic quadrant. The kinematic study shows that the η Cha cluster, as well as members of the TW Hya association and a new group near ϵ Cha, probably originated near the giant molecular cloud complex that formed the two oldest subgroups of the Sco-Cen OB association roughly 10-15 Myr ago. Their dispersal is consistent

with the velocity dispersions seen in giant molecular clouds. A large H I filament and dust lane located near η Cha has been identified as part of a superbubble formed by Sco-Cen OB winds and supernova remnants. The passage of the superbubble may have terminated star-formation in the η Cha cluster and dispersed its natal molecular gas.

Far Infrared mapping of the gas cooling along the L1448 outflow

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The molecular outflows associated with the two Class 0 sources L1448-mm and L1448-IRS3 have been mapped with the spectrometers on board the ISO satellite allowing to study in detail the physical and chemical structure of the shocked gas. The far infrared cooling is mainly due to the emission from pure rotational lines of CO, H_2O and H_2 excited at temperatures between 500 and 1200 K. [OI]$63\mu m$ emission is also widespreadly observed along the flows. Additional ground based observations of the ^{12}CO 4-3 and 3-2 transitions in the surroundings of the L1448-mm source allow us to localize this warm emission in the extreme high velocity clumps forming the collimated molecular jet responsible for the entrainment of the outflow. Our analysis shows therefore that this jet is hotter than previously thought on the basis of millimeter observations alone.
A comparison with existing models suggests that the excitation along the outflow from L1448-mm is mainly due to low velocity ($V_s \leq 20 km\,s^{-1}$) non-dissociative shocks (C-shocks) probably developed as the jet proceeds through a medium already put into motion by previous episodes of mass loss. Excitation from turbulent mixing layers along the molecular jet axis seems not able to explain the observed cooling ratios among the different molecular components.
An higher excitation shock component is likely present in the direction of the source L1448-IRS3, as testified by the detection of the [SiII] $35\mu m$ line and by a larger contribution of the [OI] emission.
Finally the abundance of gas-phase H_2O is largely enhanced with respect to its interstellar value all along the flow. Both the total luminosity of water and its abundance correlate with SiO at high excitation, implying that both H_2O and SiO are released in the low-velocity shocks developed along the outflow.

Magnetorotational Instability in Protoplanetary Disks. II. Ionization State and Unstable Regions

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We investigate where in protoplanetary disks magnetorotational instability operates, which can cause angular momentum transport in the disks. We investigate the spatial distribution of various charged particles and the unstable regions for a variety of models for protoplanetary disks taking into account the recombination of ions and electrons at grain surfaces, which is an important process in most parts of the disks. We find that for all the models there is an inner region which is magnetorotationally stable due to ohmic dissipation. This must make the accretion onto the central star non-steady. For the model of the minimum-mass solar nebula, the critical radius, inside of which the disk is stable, is about 20 AU, and the mass accretion rate just outside the critical radius is $10^{-7} - 10^{-6}$ $M_\odot$ yr^{-1}. The stable region is smaller in a disk of lower column density. Dust grains in protoplanetary disks may grow by mutual sticking and may sediment toward the midplane of the disks. We find that the stable region shrinks as the grain

size increases or the sedimentation proceeds. Therefore in the late evolutionary stages, protoplanetary disks can be magnetorotationally unstable even in the inner regions.

Tracing the Mass during Low-Mass Star Formation. I. Submillimeter Continuum Observations

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We have obtained 850 and 450 μm continuum maps of 21 low mass cores with SED's ranging from pre-protostellar to Class I ($18K < T_{bol} < 370K$), using SCUBA at the JCMT. In this paper we present the maps, radial intensity profiles, and photometry. Pre-protostellar cores do not have power-law intensity profiles, whereas the intensity profiles of Class 0 and Class I sources can be fitted with power laws over a large range of radii. A substantial number of sources have companion sources within a few arcminutes (2 out of 5 pre-protostellar cores, 9 out of 16 Class 0/I sources). The mean separation between sources is 10800 AU. The median separation is 18000 AU including sources without companions as a lower limit. The mean value of the spectral index between 450 and 850 μm is 2.8 ± 0.4, with pre-protostellar cores having slightly lower spectral indices (2.5 ± 0.4). The mean mass of the sample, based on the dust emission in a 120 arcsecond aperture, is 1.1 ± 0.9 M$_\odot$. For the sources fitted by power-law intensity distributions ($I_\nu(b)/I_\nu(0) = (b/b_0)^m$), the mean value of m is 1.52 ± 0.45 for Class 0 and I sources at 850 μm and 1.44 ± 0.25 at 450 μm. Based on a simple analysis, assuming the emission is in the Rayleigh-Jeans limit and that $T_d(r) \propto r^{-0.4}$, these values of m translate into power-law density distributions ($n \propto r^{-p}$) with $p \sim 2.1$. However, we show that this result may be changed by more careful consideration of effects such as beam size and shape, finite outer radii, more realistic $T_d(r)$, and failure of the Rayleigh-Jeans approximation.

L483: A Protostar in Transition From Class 0 to Class I

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We present molecular line observations toward the dense core in L483 and its bipolar outflow powered by the Class 0 object IRAS 18148-0440. ^{12}CO maps show that the outflow is well collimated and asymmetric, and that its gas is warmer than the surrounding cloud by at least a factor of 2. H_2CO lines toward the outflow show prominent high-velocity wings and evidence for an H_2CO abundance enhancement of a factor of 20. At ambient velocities, these lines show strong self-absorption and a brighter blue peak, a characteristic signature of inward motions. Finally, and in contrast with the outflows from other Class 0 objects, the CH_3OH lines in L483 do not show high velocity wings, and no evidence for abundance enhancement is found in this molecule or in SiO. Comparing the physical and chemical properties of the outflow in L483 with those of other outflows from Class 0 and Class I sources, we find that the L483 outflow is somewhat intermediate between these types. This suggests that the L483 central source has already started its transition from Class 0 to Class I, and that its mixed outflow properties illustrate how this transition occurs.

The response of an accretion disc to an inclined dipole

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We compute the warping of a disc induced by an inclined dipole. We consider a magnetised star surrounded by a thin Keplerian diamagnetic disc with an inner edge that corotates with the star. We suppose the stellar field is a dipole with an axis that is slightly misaligned with the stellar rotation axis. The rotation axes of the disc material orbiting at large distances from the star and that of the star are supposed to coincide. The misalignment of the magnetic and rotation axes results in the magnetic pressure not being the same on the upper and lower surfaces of the disc. The resultant net vertical force produces a warp which appears stationary in a frame corotating with the star. We find that, if viscosity is large enough ($\alpha \sim 0.01$–0.1) to damp bending waves as they propagate away, a smoothly varying warp of the inner region of the disc is produced. The amplitude of the warp can easily be on the order of ten percent of the disc inner radius for reasonably small misalignment angles (less than 30 degrees). Viscous damping also introduces a phase shift between the warp and the forcing torque, which results in the locations of maximum elevation above the disc forming a trailing spiral pattern. We apply these results to recent observations of AA Tau, and show that the variability of its light curve, which occurs with a period comparable to the expected stellar rotation period, could be due to obscuration produced by a warp configuration of the type we obtain.

Star formation in clusters: early sub-clustering in the Serpens core

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We present high resolution interferometric and single dish observations of molecular gas in the Serpens cluster-forming core. Star formation does not appear to be homogeneous throughout the core, but is localised in spatially- and kinematically-separated sub-clusters. The stellar (or proto-stellar) density in each of the sub-clusters is much higher than the mean for the entire Serpens cluster. This is the first observational evidence for the hierarchical fragmentation of proto-cluster cores suggested by cluster formation models.

Detection of the thermal radio continuum emission from the G9.62+0.19-F Hot Core

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We present new high resolution and high sensitivity multi-frequency VLA radio continuum observations of the G9.62+0.19-F hot molecular core. We detect for the first time faint centimetric radio continuum emission at the position of the core. The centimetric continuum spectrum of the source is consistent with thermal emission from ionised gas. This is the first direct evidence that a newly born massive star is powering the G9.62+0.19-F hot core.

http://www.arcetri.astro.it/~lt/preprints/preprints.html

Limits on the cosmic-ray ionization rate toward massive young stars

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Recent models of the envelopes of seven massive protostars are used to analyze observations of H_3^+ infrared absorption and $H^{13}CO^+$ submillimeter emission lines toward these stars, and to constrain the cosmic-ray ionization rate ζ_{CR}. The $H^{13}CO^+$ gives best-fit values of $\zeta_{CR} = (2.6 \pm 1.8) \times 10^{-17}$ s^{-1}, in good agreement with diffuse cloud models and with recent Voyager/Pioneer data but factors of up to 7 lower than found from the H_3^+ data. No relation of ζ_{CR} with luminosity or total column density is found, so that local (X-ray) ionization and shielding against cosmic rays appear unimportant for these sources. The difference between the H_3^+ and $H^{13}CO^+$ results and the correlation of $N(H_3^+)$ with heliocentric distance suggest that intervening clouds contribute significantly to the H_3^+ absorptions in the more distant regions. The most likely absorbers are low-density ($\lesssim 10^4$ cm^{-3}) clouds with most carbon in neutral form or in CO.

First Observations of the Magnetic Field Geometry in Pre-stellar Cores

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We present the first published maps of magnetic fields in pre-stellar cores, to test theoretical ideas about the way in which the magnetic field geometry affects the star formation process. The observations are JCMT–SCUBA maps of $\lambda 850$ μm thermal emission from dust. Linear polarizations at typically ten or more independent positions in each of three objects, L1544, L183 and L43 were measured, and the geometries of the magnetic fields in the plane of the sky were mapped from the polarization directions. The observed polarizations in all three objects appear smooth and fairly uniform. In L1544 and L183 the mean magnetic fields are at an angle of $\sim 30°$ to the minor axes of the cores. The L43 B-field appears to have been influenced in its southern half, such that it is parallel to the wall of a cavity produced by a CO outflow from a nearby T Tauri star, whilst in the northern half the field appears less disturbed and has an angle 44° to the core minor axis. We briefly compare our results with published models of magnetized cloud cores and conclude that no current model can explain these observations simultaneously with previous ISOCAM data.

astro-ph/0006069

The location of the dense and ionized gas in the NGC 2023 PDR

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The VLA and the BIMA array were used to obtain high resolution (10–20 arcsec) observations of C^+, traced by the C91α recombination line at 8.6 GHz, and the dense molecular gas, traced by HCN and HCO^+(1–0), of the photon dominated region (PDR) associated with the reflection nebula NGC 2023. Using the VLA, continuum emission is detected at 8.6 GHz from a faint H II region associated with HD 37903. The C91α emission originates from a 0.4 pc long filament, extending from the east to the south of the exciting star HD 37903. Within the filament three C91α clumps can be distinguished, each associated with filamentary vibrationally excited H_2 emission in the direction toward HD 37903. The HCO^+ emission has a clumpy appearance superimposed on a more extended component. C91α is, in general, closer to the exciting star than HCO^+ emission as expected from PDR models. The morphologies of HCO^+ and HCN are quite similar. Based on the C91α linewidth towards one of the clumps a limit of 170 K on the kinetic temperature in the ionized carbon layer can be derived. This value is consistent with PDR models with H_2 densities of about 10^5 cm^{-3}. However, this result suggests surprisingly low limits on the turbulence in the PDR. We detected a compact 3 mm continuum source in the PDR, which appears to be a cold "core" of density 10^7 cm^{-3}, 0.03 parsec diameter, and 6 $M_\odot$. We conclude that it may have formed within the PDR.

In an appendix, observations of the C91α recombination line toward five additional PDRs using the Effelsberg 100m telescope are described.

Correlations between parameters of massive cores of interstellar molecular clouds

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On the basis of the results of the CS and $C^{34}S$ survey of dense molecular cloud cores in regions of high mass star formation the correlations between line width and size ($\Delta V - L$) as well as between mean density and size ($n - L$) are analyzed. There is practically no correlation between ΔV and L ($\Delta V \propto L^{0.2 \pm 0.1}$). The velocity dispersion is several times higher than in CO and dark clouds of the same size. The mean density decreases with size much faster than L^{-1} so that the column density also decreases. A possible influence of the selection effects and of the source parameter determination procedure on these results are discussed.

Dissertation Abstracts

Treatment of Ionizing Radiation in Smoothed Particle Hydrodynamics Calculations and Application to the Dynamics of Cloud Cores in the Radiation Field of Massive Stars

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Recent observations of broadened spectral lines suggest that the dynamics of molecular clouds (MCs) are dominated by supersonic, turbulent motion. Furthermore, one observes sheet-like and filamentary structures on all resolvable scales. There exists recent theoretical work concerning the evolution of turbulent MC's and their fragmentation into dense cloud cores, which are presumably the progenitors of new stars. These calcualtions allowed to study the dynamics in MCs under the influence of thermal pressure and self-gravity. However, in high mass SF regions, the massive stars start interacting with their parental cloud via stellar winds and ionizing radiation. These feedback processes disrupt the MC by heating and ionization, but could at the same time induce new star formation by compression of the MC.

This work focused on the development of a new computational method which allows the inclusion of ionizing radiation in hydrodynamical simulations using Smoothed Particle Hydrodynamics (SPH). In contrast to grid-based methods, SPH is especially suited for investigating the fragmentation of turbulent media due to the independence from a fixed grid geometry. The implementation of ionizing radiation into SPH is an important step toward the ability to model numerically the feedback of young stars on their molecular clouds. The first application is the ionization-driven implosion of density enhancements in MC's.

http://www.mpia-hd.mpg.de/THEORY/preprints/kessel/1999/dissertation/head.html

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