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Abstracts of recently accepted papers

Molecular Evolution in Protoplanetary Disks: Two-dimensional Distributions and Column Densities of Gaseous Molecules

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We investigate the two-dimensional (R, Z) distribution of molecules in circumstellar disks around young stellar objects. In the Z-direction, the disk can be schematically divided into three layers: the midplane, the outermost surface region, and the intermediate region. On the midplane, in cool outer regions of a disk, most of the molecules are adsorbed onto grains within a short time and depleted from the gas phase owing to the high density. As the height Z increases, the density decreases and the time scale for adsorption of molecules onto the dust particles increases. At the outermost surface regions, on the other hand, molecules are dissociated by UV radiation. Hence, in disks with a typical age ($10^5 - 10^6$ yr), molecular abundances have their peak values at some intermediate region. The height at which the abundances reach their peak values varies with species. Radicals, such as CN and C_2H, have their peaks at larger heights Z than more stable species such as HCN and NH_3. At significant distances from the midplane, the chemistry is also affected by a higher ionization rate due to X-rays, if the central star is a strong X-ray emitter, while, in the midplane, cosmic-rays are the main sources of ionization. The abundances of some species (e.g. HCN) are enhanced by a higher ionization rate.

Integrating molecular abundances perpendicular to the midplane, we obtain column densities for molecules, and their radial distribution. Column densities of selected molecules such as HNC and NH_3 are particularly sensitive to the total column density of the disk and the variation in UV radiation field due to the growth and sedimentation of dust particles. Our results show reasonable agreement with molecular abundances in the DM Tau disk estimated from radio observations.

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http://www.physics.ohio-state.edu/∼aikawa

The physical properties of the HH 30 jet from HST and ground–based data

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We investigate the physical properties of the HH 30 jet by applying the spectroscopic diagnostic technique described in Bacciotti & Eislöffel (1999, A&A 342, 717) to ground-based spectra and Hubble Space Telescope (HST) calibrated emission-line images. We derive the variation along the beam of the ionization fraction x_e, of the total hydrogen density n_H and of the average excitation temperature T_e, with a spatial sampling of $0''.1$ to $0''.6$ (depending on the dataset used) near the source of the flow and of $1''.8$ further out. In the jet x_e rapidly rises from 0.065 at $0''.2$ to 0.1 at $0''.4$, and then slowly *increases* up to 0.140 within $2''$ from the source. From $2''.4$ to $12''.5$, x_e decreases very slowly down to a value of 0.04. The slow recombination in the outermost collimated part is consistent with a flow opening angle of about

2°. At the beginning of the jet $n_{\rm H}$ is at least $\sim 10^5\,{\rm cm}^{-3}$, but it decreases to $5\ 10^4\,{\rm cm}^{-3}$ within the first arcsecond and then slowly falls to $10^4\,{\rm cm}^{-3}$ at large distance from the source. On average $T_{\rm e}$ decreases from $\sim 2\ 10^4\,{\rm K}$ to $10^4\,{\rm K}$ within the first arcsecond of the jet, then it slowly decays to 6000 – 7000 K. In the faint counter-jet, which appears to be substantially more excited than the jet, $x_{\rm e}$ rises from 0.07 up to 0.35 at 2-3″ from the source, $n_{\rm H}$ decreases from about $8\ 10^4\,{\rm cm}^{-3}$ to a few $10^3\,{\rm cm}^{-3}$, while $T_{\rm e}$ is scattered around 1.2-1.3 10^4 K. A comparison between the observed and calculated line fluxes shows that *the filling factor is of order unity in this flow*. The emission-weighted jet width calculated with the parameters that we derive is in good agreement with the observed FWHM; we find, however, that the jet radius apparently goes to zero at the source location, defining an initial *full* opening angle of about 10°. The intensity peaks, i.e. the knots, are clearly correlated with local temperature maxima. The ionization fraction and the electron and total densities do not show any evident increase at the same positions, although we cannot exclude the presence of small-scale variations, because of the lower spatial resolution with which these quantities have been derived. Alternatively, the lack of large density enhancements at the locations corresponding to the knots may be due to the presence of a substantial magnetic field in the body of the jet. Anyway, the absence of evident bow-shaped features suggests that in this jet it is more likely that the chain of bright spots traces travelling plasma instabilities, rather than a series of internal working surfaces. Along the jet the mass-loss rate is quite moderate: assuming an average flow speed of 200 km s^{-1}, and adopting as our jet diameter the emission-weighted jet width, we find $\dot{M} \sim 1.7\ 10^{-9}$ M$_\odot$ yr^{-1} and correspondingly $\dot{P} \sim 3.5\ 10^{-7}$ M$_\odot$ yr^{-1} km s^{-1}. In the counter-jet, in contrast, $\dot{M}$ ($\dot{P}$) decreases from about $1.8\ 10^{-9}$ M$_\odot$ yr^{-1} ($3.6\ 10^{-7}$ M$_\odot$ yr^{-1} km s^{-1}) at 0″.6 from the source to about $9.3\ 10^{-10}$ M$_\odot$ yr^{-1} ($1.9\ 10^{-7}$ M$_\odot$ yr^{-1} km s^{-1}) further out.

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Preprint available at: http://www.tls-tautenburg.de/research/research.html

Revisiting Hipparcos data for pre-main sequence stars

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We cross-correlate the Herbig & Bell and Hipparcos Catalogues in order to extract the results for young stellar objects (YSOs). We compare the distances of individual young stars and the distance of their presumably associated molecular clouds, taking into account post-Hipparcos distances to the relevant associations and using Hipparcos intermediate astrometric data to derive new parallaxes of the pre-main sequence stars based on their grouping. We confirm that YSOs are located in their associated clouds, as anticipated by a large body of work, and discuss reasons which make the individual parallaxes of some YSOs doubtful. We find in particular that the distance of Taurus YSOs *as a group* is entirely consistent with the molecular cloud distance, although Hipparcos distances of some faint Taurus-Auriga stars must be viewed with caution. We then improve some of the solutions for the binary and multiple pre-main sequence stars. In particular, we confirm three new astrometric young binaries discovered by Hipparcos: RY Tau, UX Ori, and IX Oph.

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Veiling derivation from high to low resolution spectra of T Tauri stars

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We propose a simple and efficient approach to extract the veiling from low resolution spectra (few hundreds) of T Tauri stars. The method is based on a point to point energy balance, over large scale and deep spectral structures, between the T Tauri spectrum and a template spectrum. We validate the new algorithm, with derivations of the veiling in quasi-simultaneous high resolution (≈10000) and low resolution spectra (≈300) of the Classical T Tauri star BP Tau. For this half veiled object the results coincides within 10%. The low resolution approach is a powerful tool which

makes it possible to study variability problems in T Tauri stars, related to e.g. flare or accretion activity, in timescales as short as minutes.

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http://www-laog.obs.ujf-grenoble.fr/activites/starform/formation.html

Polarimetry of young stellar objects – III. Circular polarimetry of OMC-1

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We present the first imaging circular polarimetry of the Orion Molecular Cloud, OMC-1. The observations, taken in the J, H, K_n and nbL bands, reveal a complex pattern of circular polarisation. Globally, there is a background circular polarisation of the order of $\pm$ 2 percent in the K_n band, conforming to the typical quadrupolar patterns that have been observed in other outflow sources. Overlaying this pattern are regions of relatively high degrees of circular polarisation to the east and west of the source, IRc2, with degrees as high as +17 percent in the K_n band, the highest circular polarisation yet measured for any young stellar object. No circular polarisation is seen in the J band indicating that the circular polarisation detected at longer wavelengths originates from within OMC-1 and not from scattering off the foreground ionisation front associated with the M42 nebula.

We demonstrate a correlation between these patches of high circular polarisation and regions of enhanced linear polarisation and argue that these observations are best explained using a model which incorporates scattering of radiation off oblate grains, which have been aligned by the local magnetic field. Modelling of the ellipticity (the ratio of circular to linear polarisation) suggests that the grains are composed of silicate and/or organic refractory material and that grains larger than are typically found in the ISM are needed. The lower, background, circular polarisation is produced by scattering off randomly oriented grains in the outflow cavities, the grain alignment being destroyed by the passage of shocks.

We put forward a morphological model for OMC-1 which has the regions of high polarisation separate, but nearby, to the main outflow region. Those regions exhibiting high polarisation must somehow have a direct view of the nebula's illuminating source.

Implications of this work to the origins of life are briefly discussed.

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Preprints available from: ftp://star.herts.ac.uk/pub/Chrysostomou/papers/omc1.ps.gz

Consistency of Ambipolar Diffusion Models with Infall in the L1544 Protostellar Core

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Recent high-resolution studies of the L1544 protostellar core by Tafalla et al. and Williams et al. reveal the structure

and the kinematics of the gas. The observations of this prestellar core provide a natural test for theoretical models of core formation and evolution. Based on their results, the above authors claim a discrepancy with the implied infall motions from ambipolar diffusion models. In this paper, we reexamine the earlier ambipolar diffusion models, and conclude that the L1544 core *can* be understood to be a magnetically supercritical core undergoing magnetically diluted collapse. We also present a new ambipolar diffusion model specifically designed to simulate the formation and evolution of the L1544 core. This model, which uses reasonable input parameters, yields mass and radial density distributions, as well as neutral and ion infall speed profiles, that are in very good agreement with physical values deduced by observations. The lifetime of the core is also in good agreement with mean prestellar core lifetimes estimated from statistics of an ensemble of cores. The observational input can act to constrain other currently unobserved quantities such as the degree of ionization, and the background magnetic field strength and orientation near the L1544 core.

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Molecular outflows in intermediate-mass star forming regions: the case of CB3

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The intermediate-mass star forming region in the Bok globule CB3 has been investigated through a multiline survey at mm-wavelengths. We have detected a chemically rich bipolar outflow, driven by a probably Class 0 submillimetre source, which reveals different clumps along the main axis, indicating episodic increases of the mass loss process. The outflow is quite massive (4 $M_{\odot}$) and very powerful, since the kinetic energy is 5.5 10^{45} ergs and the mechanical luminosity is 5.6 $L_{\odot}$. The outflow motion is able to affect the structure of the globule and to clear a significant amount of the high-density gas hosting the star forming process. The dynamical flow parameters, as well as the analysis of the CO velocity profiles, place the CB3 outflow close to the HH7-11 and NGC2071 ones.

The CS maps reveal the molecular clump around the driving source, while the CS line profiles show a self-absorption feature consistent with the presence of infall motions. The CH_3OH and SiO molecules are present only along the main outflow axis, confirming their close association with outflows, and their emission allows to detect the jet-like outflow structure and to point out four clumps with size less than 0.1 pc. We have detected two episodic mass losses, with ages of about 10^4 and 10^5 yr, indicating that the CB3 outflow is in a quite evolved evolutionary stage. Moreover, also the emission of S-bearing molecules such as SO, SO_2, H_2S and OCS is definitely enhanced towards the outflow. We have derived quite high densities, close to 10^5-10^6 cm^{-3}, and the indication that SiO is tracing gas at higher density with respect to SO and CH_3OH. The SiO molecule traces the highest velocity jet-like structure, while SO and CH_3OH play an intermediate role between SiO and CO, being associated with more extended regions produced by interaction of the mass loss with the surrounding gas. We have found $SO/H_2S \sim SO_2/H_2S \geq 1$, $SO/SO_2 \simeq 1$, $OCS/H_2S \geq 1$ and $SO/SiO \gg 1$. These column density ratios, used as crude chemical clocks, indicate that the CB3 outflow in a relatively evolved evolutionary stage, in agreement with the age estimations based on its dynamics.

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Accretion in Taurus PMS binaries: a spectroscopic study

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We present low-resolution optical spectra of each component of 10 T Tauri (TT) binary systems with separations ranging from 0.9″ to 3.5″ and located in the Taurus star-forming region. We derive the spectral type and Hα equivalent width of each component.

Complementing these results with those of Monin et al. (1998) yields a sample of 14 binaries and one triple system, with resolved spectroscopy and/or near-infrared photometry. We find that mixed binaries (CTTS+WTTS) are rare, representing only 15–20 % of the systems in the separation range of 0.8" to 3″. Supplementing these results with those of Hartigan et al. (1994) and Prato & Simon (1997), we show that the trend of binary TTS to be twins holds to separations up to 13″. This is unlikely to be the result of random pairing, and confirms previous results that both stars in young binaries accrete over the same time span.

In binary systems where both stars are still accreting, our measurements show that the most massive star is usually the component with the largest accretion rate by up to a factor of 10, as determined from the Hα luminosity.

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http://laog.obs.ujf-grenoble.fr/activites/starform/formation.html

Radio continuum emission at OH and H_2O maser sites

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A search for centimeter radio continuum emission associated with OH and H_2O masers has been made toward 26 fields containing 45 separate maser sites using the Australia Telescope Compact Array (ATCA) at 8.2 and 9.2 GHz. The sensitivity achieved for fields not limited by dynamic range is ∼0.15 mJy rms. This is the deepest radio search for embedded stellar sources at sites containing OH and H_2O masers made to date.

Only 17 compact continuum sources were detected within 2″ of the 45 maser sites searched. The absence of 3 cm continuum emission at the mJy level in 62% of the maser sites shows that most OH/H_2O maser sites do not contain a well-developed UCHII region. The implications of this result on the nature of the source pumping the maser emission are discussed. While other possibilities cannot be ruled out, we argue that many maser sites without detected UCHII are most likely massive stars still in the pre-main sequence contraction stage.

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Detection of Polarized CO Emission from the Molecular Outflow in NGC 1333 IRAS 4A

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We report the first interferometric detection and mapping of linearly polarized spectral line emission due to the Goldreich-Kylafis effect. Our polarization maps of the CO J=2→1 line in the molecular outflow powered by the very young stellar system NGC 1333 IRAS 4A make it possible to define the direction of the magnetic field in the outflow. Comparison with theoretical predictions implies that the magnetic field is parallel to the polarization. Our data suggest that the deflection of the outflow may be the result of the interaction between the outflow and the magnetic field. We also detect and map the linearly polarized dust continuum emission at 1.3 mm. The polarization map of the dust continuum is roughly consistent with an hourglass magnetic field morphology, i. e., it is in agreement with theoretical models of interstellar cloud contraction with a frozen-in magnetic field. The two techniques for mapping magnetic field morphologies agree. The two techniques in general sample different column densities and together allow study of magnetic field morphology over wider areas than either alone would permit.

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http://www.astro.uiuc.edu/∼jgirart/curro.html

Evidence for inward motion in a galactic cirrus core

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Using the IRAM 30 m radiotelescope a dense core in MCLD 123.5+24.9 has been observed in the CS (J=2→1), (3→2) and (5→4) lines. In the lower two rotational lines the cloud extends over 0.03 pc × 0.15 pc at an adopted distance of 150 pc. The core harbours three dense condensations with full widths at half maximum between 4500 and 6100 AU. Based on $C^{18}O$ observations their masses are estimated to be between 0.06 and 0.12 $M_\odot$. The southernmost shows asymmetric self-absorbed CS (2→1) and (3→2) lines with the blue shifted part brighter than the red shifted; the velocity of the (5→4) transition is in between the blue and red shifted lines of the lower transitions. These features are well-tested diagnostics of inward motion in molecular clouds. An inward velocity of 4 to 10 m s^{-1} is estimated from the CS lines.

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A Keck High Resolution Spectroscopic Study of the Orion Nebula Proplyds

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We present the results of spectroscopy of four bright proplyds in the Orion Nebula obtained at a velocity resolution of 6 km s^{-1}. After careful isolation of the proplyd spectra from the confusing nebular radiation, the emission line profiles are compared with those predicted by realistic dynamic/photoionization models of the objects. The spectral line widths show a clear correlation with ionization potential, which is consistent with the free expansion of a transonic, ionization-stratified, photoevaporating flow. Fitting models of such a flow simultaneously to our spectra and *HST* emission line imaging provides direct measurements of the proplyd size, ionized density and outflow velocity. These measurements confirm that the ionization front in the proplyds is approximately D-critical and provide the most accurate and robust estimate to date of the proplyd mass loss rate. Values of $0.7\text{–}1.5 \times 10^{-6} M_\odot\,\mathrm{yr}^{-1}$ are found for our spectroscopic sample, although extrapolating our results to a larger sample of proplyds implies that $0.4 \times 10^{-6} M_\odot\,\mathrm{yr}^{-1}$ is more typical of the proplyds as a whole. In view of the reported limits on the masses of the circumstellar disks within the proplyds, the length of time that they can have been exposed to ionizing radiation should not greatly exceed 10^4 years — a factor of 30 less than the mean age of the proplyd stars. We review the various mechanisms that have been proposed to explain this situation, and conclude that none can plausibly work unless the disk masses are revised upwards by a substantial amount.

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An Infrared and Radio Study of the Galactic Worm GW46.4+5.5

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In order to study the physical properties and origin of the Galactic worm GW46.4+5.5, we have carried out high-resolution (∼3′) HI and CO (J=1−0) line observations and analyzed available infrared and radio emission survey data. GW46.4+5.5 appears as a long (∼8°), filamentary structure extending vertically from the Galactic plane in both median-filtered far-infrared and radio continuum maps. The I_{60}/I_{100} ratio in GW46.4+5.5 is estimated to be 0.29±0.05, which is significantly higher than the value determined for the solar neighborhood. The high ratio is consistent with a hypothesis that the dust grains in the worms have been processed by interstellar shocks. The

radio continuum emission from GW46.4+5.5 has spectral index $\alpha \simeq -0.47$ and does not correlate with I_{60} except for emission at low ($|b| \leq 0\overset{\circ}{.}5$) latitudes. Thus, most of the radio continuum emission is likely to be nonthermal. Our one-dimensional HI observations show that the HI gas associated with GW46.4+5.5 is mainly at $v_{\rm LSR} \simeq 15-40$ km s^{-1}. The HI gas is clumpy and we detected two molecular clouds associated with the HI peaks. The molecular clouds have large internal velocity dispersions, 8.0 and 6.6 km s^{-1}, compared to their masses, 2.8×10^3 and 1.7×10^3 $M_\odot$, which implies that they are not gravitationally bound.
Using the Leiden-Dwingeloo HI data, we identify an expanding HI supershell associated with GW46.4+5.5, which is centered on (l, b)$\simeq$(42°, 5°) with an angular size of 14°×22° (or 340×540 pc^2 at 1.4 kpc). The supershell appears between $v_{\rm LSR} \simeq 18$ and 40 km s^{-1}, and decreases slowly in size as the velocity increases. An averaged position-velocity diagram reveals that the supershell has a central velocity of ∼18 km s^{-1}, giving a kinematic distance of 1.4 kpc, and an expansion velocity of ∼15 km s^{-1}. Assuming that it has been created by multiple stellar winds and supernova explosions, we estimate its kinematic age and the energy required to produce it to be ∼5 Myr and $\sim1.5\times10^{52}$ ergs, respectively. The structure is also visible in median-filtered radio continuum maps, but not in the *ROSAT* maps. The observed molecular clouds might have condensed out of shock-compressed gas in GW46.4+5.5 because they are closely associated with the HI gas in velocity as well as in position. Their altitudes are 80 and 100 pc, respectively, higher than the scale height of the thin molecular gas disk. The physical properties of the clouds are very similar to those of the high-altitude clouds observed recently in sensitive wide-latitude CO surveys. Our results suggest that at least some of the high-altitude clouds might have formed in Galactic worms (or swept-up HI shells and supershells).

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Distance and absorption of the tails in the CG 30/CG 31/CG 38 complex. An application of a $(V-I)_0 - M_V$ main sequence relation derived from the Hipparcos and Tycho Catalogues

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From a mosaic of rather deep V and I images of the CG 30/CG 31 region we report distances and absorptions of these and other interesting interstellar features, the distances and absorptions estimates are based on shifting a new $(V-I)_0$ – M_V relation obtained from nearby, presumably unreddened Hipparcos stars with luminosity class V classification to fit confining trends in the (V−I) – V diagram. The possible success of the fit is due to the combination of the rather faint limiting magnitude of the V, I data and the inclusion of absolute magnitude in the range [1|10] and not least to the fact that M_V does not depend linearly on $(V-I)_0$ but has a gentle wavy appearance. Malmquist bias corrections are found not to be required to our intrinsic relation.

Generally speaking the blue confinements are relevant for the most distant, less reddened stars whereas the red confinements pertain to the nearest most reddened stars.

At 660 pc we find an absorption $A_V = 2.8$ mag, at ≈400 pc a possible feature with $A_V \approx 0.5^m$, and finally at 200 pc we propose a feature with $A_V = 3.6$ mag. We identify this latter feature with the windblown cometary tail of CG 31 and propose that 200 pc could be the common distance of the association of cometary globules in the Vela – CG – Annulus conversely to the generally assumed value of 400 − 450 pc. The CG 30/CG 31/ CG 38 complex may consequently be ∼200 pc removed from the Vela OB2 association. In the tail region of CG 31 the most distant main sequence stars included in the sample are observed at 2.6 kpc with $A_V = 2.8^m$, at b = -1.6° 2.6 kpc does not bring us beyond one scale height of the disk gas. In the less reddened part of the region we reach 4.4 kpc and $A_V = 1.7^m$.

Because of the excellent precision of the Hipparcos M_V determination and the good photometric accuracy of our V and I data the accuracy of $\frac{\Delta r}{r}$ is 10 – 20% if individual absorption features may be fitted with $\Delta(V-M_V) = 0.5^m$ – 1.0^m and $\Delta[\Delta(V-I)] = 0.1^m$ - 0.2^m which seems possible. The uncertainty in the $\frac{A_I}{A_V}$ ratio introduces another 5% uncertainty in $\frac{\Delta r}{r}$.

We further propose to identify the stars along the red confinement of the complete color − magnitude diagram as red clump giants at a constant distance and with absorption ranging from almost nothing to $A_V \geq 6.2^m$. Nine of these 14 stars are concentrated in a small region at 1 kpc only 2.3 pc across. In the color – magnitude diagram we find

another feature being exactly parallel to the reddening vector and located where the stellar densities seem to wane. The iso-density contours with 12 – 30 stars per (V−I,V) bin are parallel to a shifted reddening line. Assuming that these contours mainly are populated by red clump giants and that the solar distance from the Galactic Center is 8.5 kpc the shift locates these stars at 13 – 14 kpc, so maybe we have a direct measure of the Milky Way radius.

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Discovery of Young Stellar Objects at the Edge of the Optical Disk of Our Galaxy

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We report a discovery of young stellar objects associated with a molecular cloud at the edge of the optical disk of our Galaxy. This cloud is denoted as Cloud 2 in the list by Digel et al. and it is one of the most distant molecular clouds from the Galactic center known to date, with a probable distance of 15–19 kpc. We found seven red near-infrared sources associated with this cloud. Based on our near-infrared observations and far-infrared/radio data in the literature, we conclude that most sources are likely to be members of Cloud 2. The geometry of ionized gas, *IRAS* sources, near-infrared sources, and molecular cloud suggests that MR-1, an isolated early B-type star near Cloud 2, has triggered the star formation activity in Cloud 2.

Our results show that ongoing star formation is present in Cloud 2 and that active star formation can occur in the farthest regions of the Galaxy, where the molecular gas density is extremely low, perturbation from the spiral arms is very small, and the metallicity is similar to that for irregular dwarf galaxies. Cloud 2 is an excellent laboratory in which to study the details of the star formation process in an environment that is similar to that in the early stage of the formation of the Galactic disk.

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Imaging the Haro 6–10 Infrared Companion

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We present an infrared imaging study of the low-mass pre-main sequence binary system Haro 6–10. This system is one of a handful in which the optically-visible primary has the characteristics of a normal T Tauri star, while the secondary is a so-called "infrared companion" (IRC), a strongly extincted object which emits most of its luminosity in the infrared. A speckle holographic technique was used to produce nearly diffraction-limited images on three nights over a one-year period starting in late 1997. The images show that the IRC is obscured and surrounded by a compact, irregular, and variable nebula. This structure is in striking contrast to the well-ordered edge-on disk associated with HK Tauri B, the extincted companion to another T Tauri star of similar age. A new, resolved intensity peak was found $0''.4$ southwest of the IRC. We suggest that it may represent light scattered by a clump of dusty material illuminated by starlight escaping along an outflow-carved cavity in the IRC envelope. The primary star became fainter and the companion became more extended during the observing period.

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Preprints can be downloaded from http://gulliver.gps.caltech.edu

Magneto-Centrifugal Launching of Jets from Accretion Disks I: Cold Axisymmetric Flows

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The magneto-centrifugal model for jet formation is studied by time-dependent simulations reaching steady state in a gas with negligible fluid pressure, in an axisymmetric geometry, using a modification of the ZEUS3D code adapted to parallel computers. The number of boundary conditions imposed at the wind launching surface takes into account the existence of the fast and Alfvénic critical surfaces, avoiding over-determination of the flow and allowing fieldline inclination to vary in time. The size and shape of the computational box is chosen to include these critical surfaces, reducing the influence of the outer boundary conditions. As there is a region, near the origin, where the inclination θ of field lines to the axis is too small to drive a centrifugal wind ($\theta < 30^\circ$), we inject a thin, axial jet, as expected to form electromagnetically near black holes in AGN and Galactic superluminal sources. Acceleration and collimation appear for wide generic conditions. A reference run is shown in detail, with a wind leaving the computational volume in the axial direction with a poloidal velocity equal to 4 times the poloidal Alfvén speed, collimated inside an angle $\sim 11^\circ$. Finally, the critical surfaces, fieldlines, thrust, energy, torque and mass discharge of the outgoing wind are shown for simulations with various profiles of mass and magnetic flux at the base of the wind.

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Constraints on Stellar-Dynamical Models of the Orion Nebula Cluster

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The results obtained by Kroupa, Petr & McCaughrean (1999) for specific models of young compact binary-rich clusters are generalised using dynamical scaling relations, to infer the candidate set of possible birth models leading to the Orion Nebula Cluster (ONC), of which the Trapezium Cluster is the core. It is found that candidate sets of solutions exist which allow the ONC to be in virial equilibrium, expanding or contracting. The range of possible solutions is quite narrow.

These results will serve as guidelines for future, CPU-intensive calculations of the stellar-dynamical and astrophysical evolution of the entire ONC. These, in turn, will be essential to quantify observables that will ultimately discriminate between models, thus allowing us to understand if the ONC is in the process of assembling a rich Galactic cluster, and, if this is the case, how it occurs.

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Available at http://www.ita.uni-heidelberg.de/publications, or as astro-ph/9907380

A Spherical Model for "Starless" Cores of Magnetic Molecular Clouds and Dynamical Effects of Dust Grains

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In the standard picture of isolated star formation, dense "starless" cores are formed out of magnetic molecular clouds due to ambipolar diffusion. Under the simplest spherical geometry, I demonstrate that "starless" cores formed this way naturally exhibit a large scale inward motion, whose size and speed are comparable to those detected recently by Taffala et al. and Williams et al. in "starless" core L1544. My model clouds have a relatively low mass (of order 10 $M_\odot$) and low field strength (of order 10 μG) to begin with. They evolve into a density profile with a central plateau

surrounded by a power-law envelope, as found previously. The density in the envelope decreases with radius more steeply than those found by Mouschovias and collaborators for the more strongly magnetized, disk-like clouds.

At high enough densities, dust grains become dynamically important by greatly enhancing the coupling between magnetic field and the neutral cloud matter. The trapping of magnetic flux associated with the enhanced coupling leads, in the spherical geometry, to a

rapid assemblage of mass by the central protostar, which exacerbates the so-called "luminosity problem" in star formation.

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Dust Continuum Imaging of the HH 24 Region in L1630

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We have mapped the 1300 μm and 350 μm continuum emission in the region surrounding the Herbig-Haro objects HH 22 – HH 26 in L1630, which is part of the Orion B molecular cloud complex, using the MPIfR bolometer at the IRAM 30-meter telescope and the SHARC bolometer camera at the CSO. Our observations reveal the presence of a cluster of at least nine protostellar condensations at various evolutionary stages in the region around HH 24 – HH 26. In addition to two previously identified Class 0 protostars, two additional sources with a low 350/1300 μm flux ratio are detected. Although lack of FIR fluxes precludes a definitive determination of their nature, their low 350/1300 μm flux ratio along with the absence of embedded IR and radio continuum sources suggests that they are likely to be in a very early evolutionary stage. In particular, one of these two sources appears quite compact in the 1300 μm image and may be in the short-lived phase of the isothermal collapse. In addition, we have detected three millimeter continuum sources in the vicinity of the HH 22 – HH 23 objects, including a compact source at the origin of the HH 23 optical jet. The bolometric luminosity, submillimeter-to-bolometric luminosity ratio, temperature, and mass of this source are all consistent with those of a Class 0 protostar. However, the compactness of the source suggests that the continuum emission may be dominated by an unresolved disk, as would be expected for a more evolved protostellar source. No evidence is found for the presence of a molecular outflow associated with this source in our CO, ^{13}CO, and HCO^+ data obtained with the CSO.

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http://www.submm.caltech.edu/~dcl/preprints/hh24_apj.ps.gz

Strong H_2O and high-J CO emission towards the Class 0 protostar L1448-mm

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The spectrum of the Class 0 source L1448-mm has been measured over the wavelength range extending from 6 to

190 μm with the Long Wavelength Spectrometer (LWS) and the Short Wavelength Spectrometer (SWS) on the Infrared Space Observatory (ISO). The far infrared spectrum is dominated by strong emission from gaseous H_2O and from CO transitions with rotational quantum numbers $J \geq 14$; in addition, the H_2 pure rotational lines S(3), S(4) and S(5), the OH fundamental line at 119 μm, as well as emission from [OI] 63 μm and [CII] 158 μm are also observed. The strong CO and water emission can be consistently explained as originating in a warm gas component at $T \sim$700–1400 K and $n_{H_2} \sim(3\text{–}50)\,10^4\,\mathrm{cm}^{-3}$, which fills about 0.2-2% of the $\sim$75 LWS$''$ field of view (corresponding, assuming a single emitting region, to a physical size of about (3–12)$''$ or $(0.5\text{–}2)\,10^{-2}$ pc at $d = 300$ pc). We derive an H_2O/CO abundance ratio $\sim$5, which, assuming a standard CO/H_2 abundance of 10^{-4}, corresponds to $H_2O/H_2 \sim 5\,10^{-4}$. This value implies that water is enhanced by about a factor $\sim 10^3$ with respect to its expected abundance in the ambient gas. This is consistent with models of warm shocked regions which predict that most of the free atomic oxygen will be rapidly converted into water once the temperature of the post-shocked gas exceeds $\sim$ 300 K. The relatively high density and compact size inferred for this emission may suggest an origin in the shocked region along the molecular jet traced by SiO and EHV CO millimeter line emission. Further support is given by the fact that the observed enhancement in H_2O can be explained by shock conditions similar to those expected to produce the abundant SiO which is also observed in the region. L1448-mm shows the largest water abundance so far observed by ISO amongst young sources displaying outflow activity; we argue that the occurrence of multiple shocks over a relatively short interval of time, like that evidenced in the surroundings of L1448-mm, could have contributed to enrich the molecular jet with a high H_2O column density.

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Preprint available by anonymous-ftp at coma.mporzio.astro.it/pub/nisini/1448/

ISOCAM observations of the R CrA region

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The results of an ISOCAM survey of the RCrA star formation region are presented. The survey was carried out in two broad-band filters, LW2 (5–8.5 μm) and LW3 (12–18 μm). Although it was not possible to map the densest, central region due to saturation problems, 21 sources were identified which showed mid-IR excesses. Most of these sources have not previously been recognised as YSOs (Young Stellar Objects), mainly because they are relatively faint. We find evidence for a population of very low mass stars which are probably brown dwarfs in their early contraction phases.

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Detection of hard X-rays from a Class I protostar in the HH24-26 region in the Orion Molecular Cloud

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We observed the HH24-26 region in the L1630 Orion molecular cloud complex with the X-ray observatory ASCA in the 0.5−10 keV band. X-ray emission was detected from the T Tauri star SSV61 and from the region where the Class I protostars SSV63E and SSV63W are located (hereafter SSV63E+W). The spectra of both SSV63E+W and SSV61 are well explained by an optically thin thermal plasma model. The spectrum of the T Tauri star SSV61 has a low temperature of $kT = 0.9$ (0.7−1.2) keV and a moderate absorption of $N_{\rm H} = 1.3$ (0.9−1.7) $\times 10^{22}$ cm^{-2}, while that of the protostar SSV63E+W has a high temperature of $kT = 5.0$ (3.3−7.9) keV and a heavy absorption of $N_{\rm H} = 1.5$ (1.2−1.8) $\times 10^{23}$ cm^{-2}. The X-ray light curve of SSV63E+W showed a flare during the observation. The peak flux reached about 9 times that of the quiescent flux. The temperature and the absorption column density do not change conspicuously during the flare. The 0.5−10 keV luminosity of SSV63E+W was about 1×10^{32} erg s^{-1} in the quiescent state. The present detection of hard X-rays from SSV63E+W is remarkable, because this is the first X-ray detection of a protostar in Orion.

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3D transfer of the diffuse ionizing radiation in ISM flows and the preionization of a Herbig-Haro working surface

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We have developed a new 3D radiation-gasdynamic code which includes a treatment of the transfer of the diffuse ionizing radiation produced by the flow. We describe this code in some detail, and then apply it to the problem of preionization in the working surface of a Herbig-Haro (HH) jet.

This 3D numerical simulation shows the spatial structure of the precursor of a working surface of a HH jet. As has been previously described in the context of plane-parallel shocks, the diffuse radiation both ionizes and heats the preshock flow. We find that the diffuse, ionizing radiation also significantly affects the post-shock flow stratification and the location of the shocks in the simulations, likely leading to different predicted spectra for models with or without diffuse radiation. Synthetic Hα emission-line maps produced from our simulations show that the preionized region will be difficult to observe due to its faintness compared to the post-bow shock emitting region.

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Multiplicity of the HH 111 jet source: Hubble Space Telescope NICMOS images and VLA maps

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We have observed the region around the HH 111 jet source with NICMOS onboard the *Hubble Space Telescope*, using two filters, F160W and F205W, which besides stellar continuum transmit the [FeII] 1.64 μm and H_2 2.12 μm emission lines, respectively. The jet can now be traced to within 2.4 arcsec of the VLA source. In the F205W filter we detect for the first time the driving source in the near-infrared as a faint and highly reddened star. Additionally, we detect in both filters a second source, called star B, about 3″ further west, which appears to contribute significantly to the illumination of the blueshifted outflow cavity of the HH 111 jet. We present new 3.6 cm VLA maps, which show evidence that the HH 111 energy source drives a quadrupolar flow, suggesting that the source is a close binary with a

projected separation of less than 0.1 arcsec (50 AU). We also detect star B at 3.6 cm, demonstrating that it is indeed a young star with its own (unresolved) signature of outflow. The two IR/VLA sources are located on either side of a highly opaque dust lane perpendicular to the HH 111 outflow axis, not inside it as one would expect. We speculate that the VLA 1 binary and the VLA 2 source are at their present locations because they originally formed an unstable non-hierarchical triple system from which the lightest member, VLA 2, was ejected. Such dynamic processes may help in terminating the main accretion phase of the young stars involved.

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HH 46/47: Also a parsec scale flow

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We report the discovery of a pair of large Herbig-Haro type structures roughly 10 arcminutes (1.3 pc) north-east and south-west of the source driving the well-known HH 46/47 Herbig-Haro jet in new deep emission-line images made using the Wide Field Imager on the ESO/MPG La Silla 2.2-m telescope. These new images suggest that the HH 46/47 outflow is much more extensive than previously assumed, extending over a total of 2.6 pc on the sky, or over 3 pc in space, when deprojected. HH 46/47 thus also belongs to the recently-discovered class of giant Herbig-Haro flows.

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ftp://ftp.aip.de/pub/users/stanke/papers/hh46.ps.gz

Ices and extinction through Taurus and Ophiuchus

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A detailed intercomparison is made between published observations of H_2O and CO ices towards the Taurus and Ophiuchus dark clouds. The column densities of the ices are intercompared, and each compared to the visual extinction through the clouds, A_v. It is neither clear that the two clouds have different or well defined threshold extinctions for the survival of ice mantles, nor that, for each of the clouds, the thresholds for the survival of CO and H_2O mantles are different. The inclusion of new objects in Taurus (Teixeira et al. 1998) introduces a large scatter in the relations between those quantities relative to results obtained by previous authors. Lines-of-sight towards deeply embedded Young Stellar Objects in Taurus appear to show an enhancement in the amount of water-ice relative to lines-of-sight towards field stars behind that cloud. While for $A_v < 14$ mag there is a tight correlation between the water-ice column density, $N_s(H_2O)$, and A_v, the inclusion of those new objects reveals a discontinuity in the relation between $N_s(H_2O)$ and A_v. The interpretation of this discontinuity is discussed.

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Determining the extinction through dark clouds

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We discuss the problem of a consistent determination of the visual extinction to objects in and behind a dark cloud. The use of near-infrared colours is discussed, in particular the H-K colours. We concentrate on the uncertainties, with emphasis on the extinction law and on the intrinsic colours of the young stars embedded in a dark cloud. The cases of the two intensively studied nearby star-forming clouds, Taurus and Ophiuchus, are addressed.

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Circumstellar disc of β Pictoris: constraints on grain properties from polarization

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We model the positional dependence of the optical polarization (BVRI–bands) in the circumstellar disc of β Pictoris as observed by Gledhill et al. (1991) and Wolstencroft et al. (1995). The particles are spherical, have a size distribution $n(a) \sim a^{-q}$ and their number density decreases with distance from the star as r^{-s}. We consider both compact and porous grains. Varying the grain size and the exponent, s, of the density distribution as well as the refractive index of the grain material m, we find that the measured polarization, colours and brightness distribution in the disc are best reproduced by a model in which the grains are larger than interstellar grains (the minimum grain size $a_{\rm min} = 0.15\,\mu$m). The value of the maximum size is ill determined because it has little influence and was taken to be $a_{\rm max} = 100\,\mu$m. The best–fit exponents of the power laws are $q = 3.2$ and $s = 3$. The grains have in the R–band a refractive index $m_R = 1.152 - 0.005i$. Such a value is roughly appropriate for porous grains where half of the volume is ice and the other half vacuum, or where 24% of the volume consists of silicate and the remaining 76% of vacuum.

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Enhanced OH in C-type Shock Waves in Molecular Clouds

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Cosmic-ray and X-ray ionisations in molecular gas produce a weak far-ultraviolet flux through the radiative decay of H_2 molecules that have been excited by collisions with energetic electrons (the Prasad-Tarafdar mechanism). I consider the effect of this dissociating flux on the oxygen chemistry in C-type shocks.

Typically a few percent of the water molecules produced within the shock front are dissociated before the gas has cooled to 50 K. The resulting column density of warm OH rises from 10^{15} to $10^{16}\,{\rm cm}^{-2}$ as the ionisation rate is increased from $10^{-17}\,{\rm s}^{-1}$ (typical of dark clouds) to $10^{-15}\,{\rm s}^{-1}$ (adjacent to supernova remnants). These column densities produce substantial emission in the far-infrared rotational transitions of OH, and are consistent with the OH/H_2O ratios inferred from *ISO* observations of emission from molecular shocks. For high ionisation rates the column of warm OH is sufficient to explain the OH(1720 MHz) masers that occur where molecular clouds are being shocked by supernova remnants.

The predicted abundance of OH throughout the shock front will enable C-type shocks to be examined with high spectral resolution through radio observations of the four hyperfine ground state transitions of OH at 18cm and heterodyne measurements of emission in the FIR (e.g. from *SOFIA*)

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Parsec-Scale CO Outflow and H_2 Jets in Barnard 5

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New observations of the Barnard 5 IRS 1 molecular outflow, including maps in the ^{12}CO $J = 2 - 1$ transition, and

images and high resolution spectra in the H_2 $v = 1$–0 $S(1)$ line are presented. In the ^{12}CO $J = 2 - 1$ maps, the outflow has a projected length of over $30'$ (3 pc), is highly collimated with a width smaller than $2'$ (0.2 pc), with one outflow lobe containing clear evidence of a limb-brightened cavity. Like the associated Herbig-Haro flow, the CO lobes exhibit C-shaped symmetry about IRS 1. Bow or cone-shaped clumps are located at the ends of the CO outflow which are not associated with visible shocks. While the presence of Herbig-Haro objects and associated shock excited H_2 emission in the outer parts of the CO flow several arc minutes closer to the source indicate that a relatively recent mass loss episode is still transfering momentum to CO bearing gas, these terminal CO structures may provide a fossil record of a much older mass loss episode. The new observations provide support for bow shock entrainment models for the acceleration of CO bearing gas. Several $15'$ long ^{12}CO emitting filaments lie parallel to but displaced by several arc minutes from the IRS 1 outflow. These features may trace perturbations excited by magnetosonic waves triggered by major mass loss eruption episodes of IRS 1. The terminal H_2 emission closely traces the Hα and [SII] emission produced by Herbig-Haro objects located near the ends of the main CO outflow body, and is likely to be powered by shocks. However, the H_2 emission is systematically displaced downstream from the Herbig-Haro objects. Since the B5 outflow appears to lie within 13° of the plane of the sky, this displacement is not likely to be a geometric projection effect. The specific excitation mechanism may require heating by a magnetic precursor or fluorescence produced by radiation originating in the shocks associated with the Herbig-Haro objects. A compact chain of H_2 knots located within $30''$ of IRS 1 appear to delineate a bipolar jet originating from this source. This H_2 feature and the associated Hα emission bisects the limb-brightened CO cones found within $20''$ of IRS 1. The presence of both axial knots and a wide angle cavity implies that the central source may simultaneously power both a jet and a wide angle wind which are formed within 2000 AU of IRS 1. A new method is used to estimate the mass in the outflow lobes which accounts for the velocity dependence of the ^{12}CO optical depth. The resulting power law mass spectra have slopes which are much steeper than those obtained by assuming that the ^{12}CO line is optically thin in the outflow lobes, an assumption which has been frequently used in other studies. The flow orientation, outflow evolution, and the velocity at which the outflow lobes becomes optically thin also affect the mass spectrum. The source luminosity, outflow dynamic time scale, outflow strength, and the embedded nature of IRS 1 imply that it is in an intermediate evolutionary stage between a Class I and Class 0 source. We also present a new optical spectrum of HH 367 which originates from IRS 3, confirming its Herbig-Haro nature and showing evidence for different excitation conditions along the flow and variable mass ejection rates from the source.

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http://casa.colorado.edu/∼kachun/research.shtml

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Dissertation Abstracts

Circumstellar Material in Young Stellar Objects

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Ph.D degree awarded: September 1999

In my dissertation I present the results of optical, infrared and submm studies of the circumstellar environment of young stellar objects, mostly of intermediate mass. Both the circumstellar dust and gas are studied, using results from the *Hipparcos* mission, the *Infrared Space Observatory* (ISO) and several ground-based telescopes.

The basic stellar properties of a sample of Herbig Ae/Be stars (HAeBes) were derived using the astrometric data from the *Hipparcos* mission. The basic conclusion from this study is that most HAeBes in our sample must be pre-main sequence stars. An evolutionary scenario for the dissipation of dust around Herbig Ae/Be stars is outlined, based on the new stellar parameters derived from the *Hipparcos* astrometry. Using the photometry obtained by *Hipparcos*, I also study the circumstellar dust through its effect on the light of the central star as it moves in and out of our line of sight. I show that such an effect can only be seen towards Herbig Ae/Be systems with a central star of spectral type A0 or later, which is explained as being due to the evolutionary effect that Herbig Be stars are not optically visible while still contracting towards the zero-age main sequence.

I also looked in more detail at the thermal emission from dust in the disks of two Herbig Ae systems, AB Aur and HD 163296, using ISO spectroscopy and new VLA data. In both these systems, significant grain growth has already occurred. However, the degree in which this has happened, as well as the degree in which the dust has crystallized, differs greatly between these two systems of identical mass and age. Clearly other parameters than just stellar mass and age influence the dissipation speed and degree of processing of the dust in a circumstellar disk.

Another way to study circumstellar dust is through submillimeter photometry. I have followed this approach to study the dust in the star forming region associated with the Herbig stars R and T CrA, using 450 and 850 μm maps obtained with SCUBA at the JCMT. Extended emission is present throughout the region at both 450 and 850 μm. The SCUBA maps do not show an enhanced intensity at the positions of the Herbig Ae/Be stars R CrA and T CrA. Six point-like submm sources were detected in the R CrA region, of which four have not been detected before. Two of these could not be identified with a near-infrared source, making them valid new candidates for Class 0 sources.

The remainder of my dissertation is devoted to ISO spectroscopy of star forming regions. I first look in some detail at a number of individual objects (S106, Cep A East, BD+40°4124 region, T Tau). The differences found in the emission line and the solid-state spectra of these objects cannot be explained in terms of differences in orientation and mass, but must reflect an evolution of the circumstellar material. The line of sight towards the embedded YSO LkHα 225 in the BD+40°4124 region was found to have a CO_2 gas/solid ratio that is more than a factor 100 higher than that found in any other line of sight so far and may contain the most evolved molecular core known to date.

After these studies of individual systems, I focus on a larger sample, consisting of 10 embedded YSOs and 11 Herbig Ae/Be stars, to study the gas in the circumstellar environment in a more systematic way. I conclude that the infrared atomic fine structure lines and the infrared molecular emission lines are in general dominated by emission from photodissociation regions (PDRs) and/or shocks. The distinction between PDRs and shocks can be made with relative ease using infrared spectroscopy using the presence of [S I] emission (indicative of the presence of a shock), strong [C II] emission (PDR) and PAH emission (PDR). Based on these results I suggest an evolutionary scenario in which the circumstellar material around a young star changes from being heated mechanically by shocks into heated by radiation from the central star through a PDR as the star clears its surroundings.

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Announcement

SIRTF Legacy Star and Planet Formation / CS Disk Evolution Virtual (Web) Workshop

11-15 November 1999

Announcing a web workshop for discussion of SIRTF Legacy projects regarding star and planet formation and evolution of circumstellar disks.

SIRTF, due for launch in December 2001, will be the long-awaited infrared member of NASA's Great Observatories. A wealth of specifics about SIRTF can be found at the SIRTF Science Center Web site: http://sirtf.caltech.edu.

SIRTF Legacy project proposals will be due in September 2000. These are intended to be major scientific endeavors receiving large amounts of SIRTF time (many hundreds of hours) in the first year of the mission. More information about the Legacy component of SIRTF science can be found at: http://sirtf.caltech.edu/Observing/Dana_Point/Bicay/index.htm, a posted version of a talk given by Dr. Michael Bicay in the August '99 SIRTF workshop at Dana Point, CA.

A noteworthy feature of the SIRTF Legacy workshop is that it is being planned as a virtual workshop, web-based, without a physical meeting of participants. During the week of the meeting, anyone will be able to join the meeting at any time of day via its top-level web site from which one may journey to poster sessions, moderated discussions, and chat rooms.

More details will follow in the next Star Formation newsletter.

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The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter.

The Star Formation Newsletter is available on the World Wide Web, where you can access it via the ESO Portal (http://www.eso.org/gen-fac/pubs/starform/).