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Abstracts of recently accepted papers

Deuterium fractionation and the degree of ionization in the R Coronae Australis molecular cloud core

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The fractionation of D and ^{13}C in HCO^+ was investigated in the R Coronae Australis molecular cloud core. The distributions of $H^{13}CO^+$ and DCO^+ were found to be morphologically similar but their column density maxima were found to lie in different locations.

The $H^{13}CO^+/HC^{18}O^+$ abundance ratio was found to vary little from 10 within the mapped region, in excellent agreement with the $^{13}CO/C^{18}O$ abundance ratios derived earlier towards the cloud by Harjunpää & Mattila (1996). This corroborates the close relationship between HCO^+ and CO predicted by the chemistry models.

The DCO^+/HCO^+ abundance ratio ranges from 0.006 to 0.04, being lowest towards two locations near the embedded infrared source IRS 7 where the kinetic temperature, as derived from methyl acetylene (CH_3CCH) observations, is somewhat elevated. The variation of the degree of deuterium fractionation within the core is due to an increase in the kinetic temperature near the cluster of newly born stars. This temperature rise results in two effects: Firstly, the reaction $H_2D^+ \rightarrow H_3^+$ becomes faster; and secondly, an intensified desorption from grain surfaces increases the abundance of neutral atoms and molecules in the gas phase leading to the destruction of H_3^+ and H_2D^+ ions. Both processes decrease the DCO^+/HCO^+ abundance ratio. Far from the active region the derived abundances of neutral species indicate the presence of depletion onto grain surfaces.

The observations suggest furthermore that the fractional electron abundance, $\chi(e^-)$, is lowest in the dense clump near IRS 7. This region also exhibits a low degree of gas phase depletion. In fact, increased fractional abundances of neutral species such as atomic oxygen and CO lead to a decrease in the $[H_3^+]/[HCO^+]$ abundance ratio which is directly proportional to $\chi(e^-)$.

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Discovery of an Extremely Young Accreting Protostar in Taurus

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We report the discovery of a new, very young accreting Class 0 protostar in the southern part of the Taurus molecular cloud. This object, designated by IRAM 04191+1522, coincides with a cold ($T \sim 12$ K) dust continuum condensation found at 1.3 mm with the IRAM 30 m telescope $\sim$ 1' south-west of the Class I infrared source IRAS 04191+1523. Although IRAM 04191+1522 was not seen by IRAS, it is associated with a weak 3.6 cm VLA radio continuum source, a highly collimated CO bipolar outflow, and 60–850 μm emission detected by ISOPHOT and SCUBA. Molecular

line observations are consistent with the protostellar condensation currently undergoing gravitational collapse. The spectral energy distribution and low bolometric luminosity ($L_{bol} \sim 0.15\ L_{\odot}$) we derive suggest the protostellar core at the center of IRAM 04191+1522 may still be dissociating molecular hydrogen.

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Water line emission in low-mass protostars

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Using the Long Wavelength Specrometer aboard ISO, we have detected far infrared rotational H_2O emission lines in five low-mass young stellar objects in a survey of seven such sources. The total H_2O fluxes are well correlated with the 1.3 mm continuum fluxes, but – surprisingly – not with the SiO millimeter emission originating in the outflows, suggesting that the water emission arises in the circumstellar envelopes rather than in the outflows.

In two of the sources, NGC1333-IRAS4 and IRAS16293-2422, we measured about ten H_2O lines, and used their fluxes to put stringent constraints on the physical conditions (temperature, density and column density) of the emitting gas. Simple LVG modelling implies that the emission originates in a very small ($\sim$ 200 AU), dense ($\geq 10^7$ cm^{-3}) and warm ($\sim$ 100 K) region, with a column density larger than about 10^{16} cm^{-2}. The detected H_2O emission may be well accounted for by thermal emission from a collapsing envelope, and we derive constraints on the acccretion rate and central mass of NGC1333-IRAS4. We also discuss an alternative scenario in which the H_2O emission arises in an extremely dense shock very close to the central object, perhaps caused by the interaction of the outflow with the innner regions of the circumstellar envelope.

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

Derivation of veiling, visual extinction and excess flux from spectra of T Tauri stars

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This work aims to analyse within a rigorous framework, veiling, visual extinction and excess extraction from the spectra of T Tauri stars. We investigate further the method of Hartigan et al. (1989) for veiling estimate from small spectral bandwidth of a few tens of Angstroms. The calculated veiling value is sensitive to the estimated noise ratio and to spectral mismatches between the object and the reference. We show that an incorrect input noise ratio together with low contrast spectra in noise units can lead to important biasses and we propose solutions to minimize this problem. In case of spectral mismatches and for large contrast spectra compared to the residual of the veiling equation, the relative veiling bias is dominated by the apparent veiling of the reference with respect to the correct underlying object stellar spectrum. The veiling error is found to be proportional to the square of the veiling when the latter becomes larger than unity. If we are limited by the statistical noise, it is little dependent on the spectral resolution. Because of systematic errors, however, it will be difficult to estimate the veiling in a very small bandwidth at spectral resolutions of a few hundreds.

For visual extinction and excess estimates, we generalize the discrete method of Gullbring et al. (1998) by a continuous approach. This new approach, which uses the spectra as a whole through a continuous modelling, has been successfully tested on simulated data. The visual extinction error is proportional to the veiling when the veiling becomes larger than unity and to a function which depends on the input reference spectrum. This function decreases with increasing spectrum contrast, which means going from earlier to later spectral types. If we are limited by the statistical noise, it is, like the veiling, little dependent on the spectral resolution. For very active T Tauri stars or when the excess is dominated by emission lines, however, it will be difficult to handle very low spectral resolutions, because of systematic errors. The real sensitivity to biasses and the performances of the algorithm are to be studied experimentally. Nevertheless, an efficient use of all the information contained in the spectra through the proposed "continuous" approach, together with a better understanding of the sources of bias, can greatly help to derive the visual extinction and the excess on objects much fainter than those so far studied.

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Detection of the CN Zeeman Effect in Molecular Clouds

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Observations of the Zeeman effect in the 3-mm lines of CN have been carried out with the 30-m IRAM telescope toward seven dense molecular clouds. Detections were achieved toward the Orion Molecular Cloud 1 (OMC1) and toward two cores in the DR21OH molecular cloud, and probably toward the M17SW molecular cloud. The line-of-sight magnetic field strengths inferred are B_{los}(OMC1) $= -0.36 \pm 0.08$ mG, B_{los}(DR21OH$_1$) $= -0.36 \pm 0.10$ mG, B_{los}(DR21OH$_2$) $= -0.71 \pm 0.12$ mG, and B_{los}(M17SW) $= -0.33 \pm 0.14$ mG. Typical molecular cloud core densities and masses sampled by these CN Zeeman detections are n(H$_2$) $\approx 10^6$ cm^{-3} and 50 $M_\odot$. Conclusions are the following: (1) Although in these clouds the gas velocities are supersonic, they are approximately equal to the Alfvén velocity, which suggests that supersonic motions are due to MHD waves. (2) The ratios of thermal to magnetic pressures $\beta_p \approx 0.5$. (3) The mass-to-magnetic flux ratios are supercritical by a factor of 2-3. (4) The cloud cores are in approximate virial equilibrium, with the kinetic dominating the magnetic energy term.

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Preprints: http://www.astro.uiuc.edu/preprints/crutcher/

Sh 138: a compact H II region excited by a very young cluster

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We present a photometric and spectroscopic study of the compact H II region Sh 138 and its associated stellar cluster. The positions and *BVRIJHK* magnitudes are obtained for more than 400 stars over a field of about 4′ square centred on the H II region. Sh 138 is excited by a cluster of young massive stars. At the cluster's very centre are at least four O–B2 stars separated by less than 4″. The brightest of these, both in the visible and the near infrared, exhibits a spectrum similar to those of the more massive Herbig Ae/Be stars. This star, our No. 183, is overluminous by a factor of 2.5 in the visible and four in the near IR with respect to the O9.5 V star required to account for the ionization level of the H II region. However star 183's position in the $J-H$ versus $H-K$ diagram does not indicate a near-IR excess. We suggest that this star is a young massive object belonging to a binary or multiple system.

The stellar cluster associated with Sh 138 is very reminiscent of the Orion Trapezium cluster: it is centrally peaked around several massive stars, and is dense – more than 550 stars pc^{-2} at its centre. The visual extinction in the cluster varies between 5 mag and more than 35 mag; large variations are observed over very small scales (for example, more than 20 mag over less than $4''$ among the central massive stars).

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Magnetic Dipole Microwave Emission from Dust Grains

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Thermal fluctuations in the magnetization of interstellar grains will produce magnetic dipole emission at $\nu \lesssim 100\,\mathrm{GHz}$. We show how to calculate absorption and emission from small particles composed of material with magnetic as well as dielectric properties. The Kramers-Kronig relations for a dusty medium are generalized to include the possibility of magnetic grains.

The magnetic permeability as a function of frequency is discussed for several candidate grain materials. Iron grains, or grains containing iron inclusions, are likely to have the magnetic analogue of a Fröhlich resonance in the vicinity of $\sim 50-100\,\mathrm{GHz}$, resulting in a large magnetic dipole absorption cross section.

We calculate the emission spectra for various interstellar grain candidates. While "ordinary" paramagnetic grains or even magnetite grains cannot account for the observed "anomalous" emission from dust in the $14-90\,\mathrm{GHz}$ range, stronger magnetic dipole emission will result if a fraction of the grain material is ferromagnetic, as could be the case given the high Fe content of interstellar dust. The observed emission from dust near 90 GHz implies that not more than $\sim 5\%$ of interstellar Fe is in the form of metallic iron grains or inclusions (e.g., in "GEMS"). However, we show that if most interstellar Fe is in a moderately ferromagnetic material, with the magnetic properties suitably adjusted, it could contribute a substantial fraction of the observed $14-90\,\mathrm{GHz}$ emission, perhaps comparable to the contribution from spinning ultrasmall dust grains. The two emission mechanisms can be distinguished by measuring the emission from *dark clouds*.

If ferromagnetic grains consist of a single magnetic domain, and are aligned, the magnetic dipole emission will be linearly polarized, with the polarization depending strongly on frequency.

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Low-mass binaries in the young cluster IC 348: implications for binary formation and evolution

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We report on a near-infrared adaptive optics survey of a sample of 66 low-mass members of the pre-main sequence stellar cluster IC 348. We find 12 binary systems in the separation range $0.1''$–$8''$, excluding 3 probable background projected companions. An estimate of the number of faint undetected companions is derived, before we evaluate the binary frequency in this cluster. In the range $\log P = 5.0$–7.9 days, the binary fraction in IC 348 is 19 ± 5 %. This is similar to the values corresponding to G- and M-dwarfs in the solar neighbourhood population (23 ± 3 % and $\sim 18\%$, respectively). Furthermore, the distribution of orbital periods of IC 348 binaries in this range is consistent with that of field binaries. We conclude that there is no binary excess in IC 348.

Substellar companions are found to be rare, or even missing, as companions of low-mass stars in the separation range we surveyed. Also, the mass ratio distribution is not peaked at $q \approx 1$ in IC 348, and it is unlikely that an observational bias can account for that.

We do not find any evidence for an evolution of the binary frequency with age within the age spread of the cluster of about 10 Myr. Comparing the binary frequency in IC 348 with that of other star forming regions (SFRs) and young open clusters, we conclude that there is no significant temporal evolution of the binary fraction between a few Myrs after the formation process and the zero-age main sequence (ZAMS) and field populations. We find instead a trend for the binary fraction to be inversely correlated with stellar density, with dense clusters having a binary fraction similar to that of field dwarfs and loose associations exhibiting an excess of binaries. Two scenarios can be suggested to explain these differences: either all SFRs, clusters and associations alike, initially host a large number of binaries, which is subsequently reduced only in dense clusters *on a timescale of less than 1 Myr* due to numerous gravitational encounters, or specific initial conditions in the parental molecular clouds impact on the fragmentation process leading to intrinsically different binary fractions from one SFR to the other.

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The initial stellar mass function from random sampling in hierarchical clouds II: statistical fluctuations and a mass dependence for starbirth positions and times

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Observed variations in the slope of the initial stellar mass function (IMF) are shown to be consistent with a model, introduced previously, in which the protostellar gas is randomly sampled from clouds with self-similar hierarchical structure. RMS variations in the IMF slope around the Salpeter value are ± 0.4 when only 100 stars are observed, and ± 0.1 when 1000 stars are observed. Similar variations should be present in other stochastic models too.

The hierarchical-sampling model reproduces the tendency for massive stars to form closer to the center of a cloud, at a time somewhat later than the formation time of the lower mass stars. The systematic variation in birth position results from the tendency for the trunk and larger branches of the hierarchical tree of cloud structure to lie closer to the cloud center, while the variations in birth order result from the relative infrequency of stars with larger masses.

The hierarchical cloud sampling model has now reproduced most of the reliably observed features of the cluster IMF. The power law part of the IMF comes from cloud hierarchical structure that is sampled during various star formation processes with a relative rate proportional to the square root of the local density. These processes include turbulence compression, magnetic diffusion, gravitational collapse, and clump or wavepacket coalescence, all of which have about this rate dependence. The low mass flattening comes from the inability of gas to form stars below the thermal Jeans mass at typical temperatures and pressures. The thermal Jeans mass is the only relevant scale in the problem. Considerations of heating and cooling processes indicate why the thermal Jeans mass should be nearly constant in normal environments, and why this mass might increase in starburst regions. In particular, the relative abundance of high mass stars should increase where the average density of the interstellar medium is very large; accompanying this increase should be an increase in the average total efficiency of star formation. Alternative models in which the rate of star formation is independent of density and the local efficiency decreases systematically with increasing stellar mass can also reproduce the IMF, but this is an adjustable result, not a fundamental property of hierarchical cloud structure, as is the preferred model.

The steep IMF in the extreme field is not explained by the model but other origins are suggested, including one in which massive stars in low pressure environments halt other star formation in their clouds. In this case, the slope of the extreme field IMF is independent of the slope of each component cluster IMF, and is given by $(\gamma - 1)/\alpha$ for cloud mass function slope $-\gamma \sim -2$ and power law relation, $M_L \propto M_c^\alpha$, between the largest star in a low-pressure cloud, M_L, and the cloud mass, M_c. A value of $\alpha \sim 1/4$ is required to explain the extreme field IMF as a superposition of individual cluster IMFs. We note that the similarity between cluster IMFs and the average IMF from global studies of galaxies implies that most stars form in clusters and that massive stars do not generally halt star formation in the same cloud.

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Luminous variables in the Quintuplet cluster

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We report observations of variability amongst the stars of the "Quintuplet" cluster located about 30 pc in projection from the centre of the Galaxy. Two of the five cocoon star members, which may be protostars or peculiar Wolf-Rayets, are seen to vary slowly with moderate amplitude (0.4–0.5 mag). The bright star within the "Pistol" HII region, suspected of being a Luminous Blue Variable (LBV), has in fact been found to show variability, confirming its tentative classification. A second nearby presumed LBV also varies. One of the apparent Quintuplet members is likely to be a Mira variable along the same line of sight.

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The origin of the protostellar jet GGD 34

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GGD 34 is a protostellar jet with wiggles which are accompanied by "sine-like" variations in the radial velocity of the emitting material by as much as 60 km s^{-1}. Thus GGD 34 is an interesting object to understand the physical mechanisms involved in the generation of wiggles in protostellar jets.

In this work we present high resolution images obtained with the Canada-France-Hawaii Telescope (CFHT) which shows that GGD 34 consists of a narrow (unresolved) jet roughly bisecting an extended faint envelope. The [S II] emission from the working surface has an arrow shaped morphology; the body of the jet is clearly distinguished as well as two backtails disposed in an approximately symmetric manner with respect to the jet axis. The Hα emission is concentrated at the head of the jet indicating that the gas is significantly more excited at this location (in particular at the so-called Knot 5); we suggest that Knot 5 traces the location of the Mach disk since spectra of GGD 34 indicate that it is a light beam of gas. The high resolution images also show that the envelope around GGD 34 connects smoothly with the back tails at the head of the jet. We speculate whether it traces the backflow; the expected backflow velocity is shown to be ~ 32 km s^{-1} which is consistent with the degree of excitation of the envelope. However, an accurate determination of the proper motion of the head is necessary to check whether this interpretation is correct.

We also present radiocontinuum (3.6 and 6 cm) VLA observations and report the detection of a radio source close to the apex of the cavity from which the jet emerges. This radio source has a spectral index of 0.7 ± 0.5, consistent within error with the value of 0.6 expected for a thermal jet. We suggest that this radio object is associated with the source of the outflow. Additional ^{12}CO(3–2) observations obtained with the JCMT show molecular gas redshifted by ~ 2.5 km s^{-1} with respect to the cloud at this location.

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Deflection of stellar jets by ambient magnetic fields

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We deal with the question whether the deflection of stellar jets/outflows that is observed for example in L 1221 can

be caused by strong ambient magnetic fields. We present results of fully three-dimensional (3D) numerical magneto-hydrodynamics (MHD) simulations of adiabatic jets propagating into an initially homogeneous medium containing an oblique magnetic field. In our model, the jet is longitudinally magnetized by a field of the strength of the x-component of the ambient magnetic field. We varied the jet velocity v_j (in the range 2 to 40 km s^{-1}), the ambient magnetic field strength B_a (50, 100 μG), and the angle α (10^o to 70^o) between the initial jet velocity and the ambient field to find the dependence of the critical velocity $v_{\rm cr}$ (up to which a jet is deflected by the magnetic field) on B_a and α. Our numerical results indicate that $v_{\rm cr}$ is a decreasing function of the field angle α. We find a nearly linear dependence of $v_{\rm cr}$ on the ambient field strength B_a. Our numerical results are in good qualitative and rough quantitative agreement with an analytical model derived from a two-dimensional consideration of the ram pressure balance governing the motion of the jet head. This model predicts an unrealistically high ambient field strength of ~ 1000 μG to deflect a jet of 100 km s^{-1} (appropriate to stellar jets). Applying our results to L 1221 and HH 110/HH 270 we thus suggest that in these sources the jet/outflow must interact with a relatively strong magnetic field (≥ 100 μG) contained in a dense clump of ambient gas ($n \geq 10^4$ cm^{-3}) if deflection is to be caused by magnetic forces. In the case of L 1221 two other possible explanations of the observational data can be given by assuming (i) that only a low speed wind surrounding the driving jet is bent by an ambient field while the outflow-driving jet itself remains straight and invisible due to high obscuration by ambient material, or (ii) that the outflow contains no high speed driving jet at all and can therefore be deflected by a moderate ambient field (≤ 200 μG).

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ftp://ftp.mpifr-bonn.mpg.de/pub/incoming/jsb/deflection.ps.gz

X-ray Ionization of the Disks of Young Stellar Objects

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We have developed a Monte Carlo code for the transport of stellar X-rays in an axially-symmetric disk. The code treats Compton scattering and photo-electric absorption and follows the X-rays until they are completely absorbed. We confirm that hard X-rays from a low-mass young stellar object (YSO) penetrate the associated accretion disk. Even without the low-energy photons that are strongly attenuated by the YSO wind, the ionization rate in the inner region of the accretion disk (< 1 AU) is many orders of magnitude larger than the standard ionization rate due to galactic cosmic rays. At a fixed radius from the source, the X-ray ionization rate is a universal function of the *vertical column density*, independent of the structural details of the disk. The ionization rate scales with the X-ray luminosity and depends only mildly on the X-ray temperature, at least for the temperatures relevant for low-mass YSO. Thus X-rays from a YSO can ionize regions of an accretion disk from which low-energy cosmic rays are excluded, e.g., by the action of stellar winds. Using a simple theory for the electron fraction we estimate that, for a minimum solar nebula, X-rays ionize the disk beyond 5 AU at a level sufficient to couple magnetic fields and neutral disk material. Inside this radius, the X-rays are ineffective for vertical column densities much larger than $\sim 10^{25}$ cm^{-2}, and thus an interior region of the disk will be uncoupled from magnetic fields. If disk accretion is mediated by MHD turbulence, as proposed by Balbus and Hawley, then our results suggest that layered accretion occurs in the inner regions of a disk ionized by X-rays, in accord with Gammie's suggestion based on cosmic-ray ionization.

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Reconnection in a Weakly Stochastic Field

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Magnetic reconnection is important for star formation. Fast reconnection is an efficient way of removing magnetic

flux from molecular clouds. We argue that the reconnection is generically fast.

We examine the effect of weak, small scale magnetic field structure on the rate of reconnection in a strongly magnetized fully ionized plasma. This structure affects the rate of reconnection by reducing the transverse scale for reconnection flows, and by allowing many independent flux reconnection events to occur simultaneously. Allowing only for the first effect and using Goldreich and Sridhar's model of strong turbulence in a magnetized plasma with negligible intermittency, we find a lower limit for the reconnection speed $\sim V_A \mathcal{R}_L^{-3/16} \mathcal{M}^{3/4}$, where V_A is the Alfvén speed, $\mathcal{R}_L$ is the Lundquist number, and $\mathcal{M}$ is the large scale magnetic Mach number of the turbulence. We derive an upper limit of $\sim V_A \mathcal{M}^2$ by invoking both effects. We argue that generic reconnection in turbulent plasmas will normally occur at close to this upper limit. The fraction of magnetic energy that goes directly into electron heating scales as $\mathcal{R}_L^{-2/5} \mathcal{M}^{8/5}$, and the thickness of the current sheet scales as $\mathcal{R}_L^{-3/5} \mathcal{M}^{-2/5}$. A large fraction of the magnetic energy goes into high frequency Alfvén waves. The angle between adjacent field lines on the same side of the reconnection layer is $\sim \mathcal{R}_L^{-1/5} \mathcal{M}^{6/5}$ on the scale of the current sheet thickness. We claim that the qualitative sense of these conclusions, that reconnection is fast even though current sheets are narrow, is almost independent of the local physics of reconnection and the nature of the turbulent cascade. As the consequence of this the Galactic and Solar dynamos are generically fast, i.e. do not depend on the plasma resistivity.

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Inelastic Dissipation in a Freely Rotating Body. Application to Cosmic-Dust Alignment

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Polarized radiation from dust is a useful tool for studying magnetic field in molecular clouds. The degree of polarization depends on the efficiency of internal dissipation of energy within a rotating grain. Motivated by a recent study by Lazarian and Draine, which showed that a high degree of grain alignment of the paramagnetic dust is achievable if the rates of internal relaxation are controlled by the Barnett relaxation process, we undertake a study of an alternative mechanism of internal dissipation, namely, the inelastic dissipation of energy in oblate dust grains. We find that deformations at double frequency that were disregarded in earlier studies dominate the inelastic relaxation. Our results show that for sufficiently oblate grains, e.g. for grains with 4:1 axis ratio, or/and grains formed by agglomeration the inelastic relaxation dominates the Barnett relaxation within large ($a > 0.1$ μm) grains. For grains with axis ratio less than 1:2 the inelastic relaxation is dominant for suprathermally rotating grains.

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Preprints are available on the WWW: http://astro.princeton.edu/~ library/prep.html POP-784

The cooling of astrophysical media by H_2

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We have computed the rate of radiative energy loss from a gas containing H_2 which is collisionally excited by H, He, and H_2. For this purpose, we used the results of recent quantum mechanical calculations of the cross sections for rovibrational transitions between all the energy levels up to approximately 20 000 K above the ground state. The temperature dependence of the rate coefficients for collisional de-excitation was found to be well represented by a simple functional form. The cooling function has been evaluated in steady state on a grid covering a wide range of values of the gas density and temperature, the atomic to molecular hydrogen density ratio, and the ortho- to para-H_2

ratio. A Fortran program is provided for the purpose of rapid numerical interpolation to any desired set of values of these parameters. The properties of the cooling function are discussed, as are the timescales required for the attainment of steady state.

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A Catalogue of Optically Selected Cores

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We present a new catalogue of 406 dense cores optically selected by using the STScI Digitized Sky Survey (DSS). In this catalogue 306 cores have neither an Embedded YSO (EYSO) nor a Pre-Main-Sequence (PMS) star, 94 cores have EYSOs (1 core has both an EYSO and a PMS star), and 6 cores have PMS star only. Our sample of dense cores in the catalogue is fairly complete within a category of northern Lynds class 5, 6 clouds, and southern Hartley et al. (1986)'s class A clouds, providing a database useful for the systematic study of dense cores. Most of the cores listed in the catalogue have diameters between $0.05 - 0.36$ pc with a mean of ~ 0.24 pc. The sizes (~ 0.33 pc in the mean) of cores with EYSOs are found to be usually larger than the sizes (~ 0.22 pc in the mean) of starless cores. The typical mean gas density of the cores is $\sim 7 \times 10^3$ cm^{-3}. Most of the cores are more likely elongated than spherical (mean aspect ratio: ~ 2.4). The ratio of the number of cores with EYSOs to the number of starless cores for our sample is about 0.3, suggesting that the typical lifetime of starless cores is $0.3 - 1.6$ Myr, about 3 times longer than the duration of the Class 0 and Class I phases. This lifetime is shorter than expected from models of ambipolar diffusion, by factors of $2 - 44$.

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Molecular and Ionised Gas Motions in the Compact HII region G29.96–0.02

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We present a new observation of the compact HII region, G29.96–0.02, that allows us to compare the velocity structure in the ionised gas and surrounding molecular gas directly. This allows us to remove most of the remaining ambiguity about the nature of this source. In particular, the comparison of the velocity structure present in the $4^{1,3}$S–$3^{1,3}$P HeI lines with that found in the 1–0 S(1) H_2 line convincingly rules out a bow shock as being important to the kinematics of this source. Our new observation therefore agrees with our previous conclusion, drawn from a velocity resolved HI Brγ map, that most of the velocity structure in G29.96–0.02 can largely be explained as a result of a champagne flow model. We also find that the best simple model must invoke a powerful stellar wind to evacuate the 'head' of the cometary HII region of ionised gas. However, residual differences between model and data tend to indicate that no single simple model can adequately explain all the observed features.

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Search for X-ray emission from bona-fide and candidate brown dwarfs

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Following the recent classification of the X-ray detected object V410 x-ray 3 with a young brown dwarf candidate (Briceño et al. 1998) and the identification of an X-ray source in Chamaeleon as young bona-fide brown dwarf (Neuhäuser & Comerón 1998), we investigate all ROSAT All-Sky Survey and archived ROSAT PSPC and HRI pointed observations with bona-fide or candidate brown dwarfs in the field of view with exposure times ranging from 0.13 to 221 ks, including dedicated 64 ks and 42 ks deep ROSAT HRI pointed observations on the low-mass star BRI 0021−0214 and the brown dwarf Calar 3, respectively. Out of 26 bona-fide brown dwarfs, one is newly detected in X-rays, namely ρ Oph GY 202. Also, four out of 57 brown dwarf candidates studied here are detected in X-rays, namely the young Taurus brown dwarf candidates MHO-4, MHO-5, V410 Anon 13, and V410 x-ray 3. The M9.5-type star BRI 0021−0214 is not detected. In the appendix, we also present catalogued, but as yet unnoticed B- and R-band data for some of the objects studied here.

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High Angular Resolution Millimeter Wave and Near–Infrared Imaging of the Ultracompact H II Region G29.96–0.02

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We present a high angular resolution study of the cometary–shaped ultracompact H II region G29.96–0.02. We have obtained $\sim 10''$ angular resolution millimeter wave maps of the region in transitions of ^{13}CO, C^{18}O, CH_3CN, CH_3OH, and CS with the BIMA interferometer. We combine these data with complementary single dish data of the ^{13}CO, C^{18}O, and CS lines taken with the FCRAO 14 meter telescope. These data are compared to near-infrared JHK–band images with $\leq 0.9''$ angular resolution obtained with the Calar-Alto 3.5 meter telescope.

The ^{13}CO data shows emission extended over a 3 pc × 2 pc region; however, the emission is strongly peaked near the head of the H II region. Strong CS, C^{18}O and CH_3CN emission peak near the same location. The CH_3CN ($J = 6 \rightarrow 5$) emission peaks toward the hot core previously detected in VLA NH_3(4,4) observations, and we determine a kinetic temperature of 100 K in the core using an LVG analysis of the CH_3CN ($6 \rightarrow 5$) BIMA data and $CH_3CN/CH_3^{13}CN$ ($5 \rightarrow 4$) IRAM data. We also find that the sharply peaked C^{18}O, ^{13}CO, and CS emission is indicative of a density gradient, with the peak density located in front of the head of the cometary H II region.

We use our near–infrared data to search for sources embedded in the H II region and adjacent cloud. In addition to the exciting star of the H II region, we identify a second star toward the head of the H II region with an extinction similar to that of the exciting star; this appears to be a second OB star in the H II region. Directly in front of the H II region, we detect a highly reddened source, which is most likely a young star deeply embedded in the molecular gas. Furthermore, we find an enhanced density of sources with $H - K > 1$ toward the molecular cloud and argue that these sources form an embedded cluster.

Finally, we compare our results to current models of cometary shaped H II regions. Given the evidence that the G29.96 H II region exists in a gradient of molecular gas density which peaks in front of the head of the H II region, we favor the champagne flow model for this region. Comparing the measured densities, temperatures and linewidths of the ionized and molecular gas, we estimate the expansion speed of the H II region into the molecular core at 2–5 km s^{-1}.

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Davis-Greenstein alignment of oblate spheroidal grains

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Davis-Greenstein alignment is important for molecular clouds. We present extensive calculations on the efficiency of grain alignment by the Davis-Greenstein mechanism. We model the grains as oblate spheroids with arbitrary axis ratios. Our description of the grain dynamics includes (i) magnetic dissipation and the inverse process driven by thermal fluctuations in the grain magnetization; (ii) gas-grain collisions and thermal evaporation of molecules from the grain surface; (iii) the transformation of rotational energy into heat by the Barnett effect and the inverse process driven by thermal fluctuations; and (iv) rapid Larmor precession of the grain angular momentum about the interstellar magnetic field. For ordinary paramagnetic grains, we calculate the Rayleigh reduction factor, R, for more than 1000 combinations of the 3 dimensionless parameters which characterise the alignment. For superparamagnetic grains we calculate R from an exact analytic solution for the relevant distribution function. We calibrate the accuracy of a recently-proposed perturbative approximation and show that it yields R values with a mean error $\sim 17\%$.

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Class II methanol masers - planets around an O-star

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Using A–configuration of the BIMA Array with $0''.4$ angular resolution, maps were obtained of the 107 GHz methanol maser in W3(OH) – a young, massive O-star with ultra-compact HII region. The 107 GHz masers have their counterparts in another methanol transition, at 6.7 GHz. The strongest maser spots are unresolved with the BIMA–array, and are less than $0''.15$, which corresponds to the lower limit of the brightness temperature 5×10^5 K. A model of Class II methanol masers originating in the extended atmosphere of icy planets which orbit around the O-star which excites the ultracompact HII region is proposed.

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Rotational modulation of X-ray flares on late-type stars: T Tauri Stars and Algol

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We present evidence for rotational modulation of X-ray flares by an analysis of four outbursts on late-type stars. Two of the flares we discuss are found in *ROSAT* observations of T Tauri Stars and were obtained between September and October 1991. A flare on the T Tauri Star V773 Tau was observed by *ASCA* in September 1995. To this sample we add a *Ginga* observation of a flare on Algol observed in January 1989.

The structure of the X-ray lightcurves observed in this selection of flare events is untypical in that the maximum emission extends over several hours producing a round hump in the lightcurve instead of a sharp peak. We explain this deviation from the standard shape of a flare lightcurve as the result of a flare erupting on the back side of the star and gradually moving into the line of sight due to the star's rotation. Making use of the known rotational periods of the stars our model allows to determine the decay timescale of the flares and the size of the X-ray emitting volume according to the standard magnetic loop model. Spectral information, which is available in sufficient quality for the Algol observation only, supports our proposition that changes of the visible volume are responsible for the observed time development of these flares.

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Nature of M8E – One of the Strongest Class I Methanol Maser

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Results are given of the analysis of multi-frequency study in methanol lines from part of the gas-dust complex M8E-IR

containing a peculiar object – Class I methanol maser. A spatial distribution of the methanol maser, IRAS source and compact radio source was determined. It was shown that the Class I methanol maser is located between the infrared and radio sources, and is probably associated with the front of bipolar outflow, in the region of its interaction with the dense molecular gas. The maser however is not involved in the bipolar motion. It is shown that the position of the Class I maser coincides with the position of OH maser within 1″.

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An unusual methanol maser 345.01+1.79

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Spectra of 345.01+1.79 obtained in multifrequency observations in methanol lines of Class I and II at 44, 95, 107, 108, 133, 157, 165, and 229 GHz were analyzed. Angular distribution of condensations where maser and thermal lines are formed was determined. All strong Class II maser lines originate from the southern spot with radial velocities from −24 to −14 km/s. The thermal lines in Class II transitions have radial velocities betwenn −14 and −11 km/s, which is close to the radial velocity of the parent molecular cloud and to the radial velocity of weak Class II maser emission from the northern spot. The Class I masers tend to the southern spot although the radial velocity is different. This source is unique in the sense that it contains the only known methanol maser at 108 GHz, and one of the small number of the strong methanol masers at 157 GHz.

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Hot Class I Methanol Maser

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Multifrequency observations of W33Met in different methanol transitions show that there co-exist four types of methanol emission sources: a Class I maser with a strong gain and narrow spectral features, a Class I quasi-maser with a low gain and with little spectral narrowing of the lines, a source of thermal emission in Class II lines, and a very weak Class II maser. The evolutionary status of these objects is different: the narrow and very bright Class I maser lines probably belong to a very young condensation, perhaps, the youngest protostar among the all observed, whereas the thermal lines, Class I quasi-maser and the weak Class II maser are probably distributed around older protostars. The estimates of physical parameters based on observations of the lines from the maser condensations show that the Class I masers are produced in a unique molecular core, which is very hot and very dense: $T_k \approx 100$ K, n=6x10^{7} $^{-3}$.

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Spectroscopic study of the Herbig Be star HD 100546

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We present new results of a spectroscopic investigation performed for the ≈10 Myr old Herbig Be star HD 100546. The data were collected during the period from 1992 to 1995 and consist of 80 high resolution spectra for Hα, Hβ, HeI 5876 Å, and NaI D lines. The line profiles show rather significant variability on time scales from less than a day to months. The analysis of these data gave arguments in favour of a circumstellar disk in an active mass exchange with HD 100546. In addition, the data also show that accretion and stellar wind may be two independent sources of activities on HD 100546, and the coexistence of them can result in the formation of an additional envelope at the sides of the equatorial disk. Two episodes of fast discrete accretion were noted during the observed period. In the first one, a red-shifted absorption was developed for the Balmer lines during two nights in 1992 June. A detailed

analysis of this event allowed us to propose a geometrical model for the circumstellar disk responsible for the observed phenomenon. The second event, was observed when the object was in state of photometric minimum in 1994 March. During this season, a number of variable features positionally moving toward higher velocities could be identified on the Hα profiles. A study of the kinematical characteristics of this moving features lead to the conclusion that a star-grazing comet-like body may be the source of this fast discrete accretion.

In addition, an analysis of the distribution of the interstellar medium toward the region of the sky containing HD 100546 gives strong evidence for the physical association between this star and the dark cloud DC296.2−7.9.

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A High Resolution Study of the Slowly Contracting, Starless Core L1544

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We present interferometric observations of N_2H^+(1–0) in the starless, dense core L1544 in Taurus. Red-shifted self-absorption, indicative of inward motions, is found toward the center of an elongated core. The data are fit by a non-spherical model consisting of two isothermal, rotating, centrally condensed layers. Through a hybrid global-individual fit to the spectra, we map the variation of infall speed at scales $\sim$ 1400 AU and find values $\sim$ 0.08 km s^{-1} around the core center. The inward motions are small in comparison to thermal, rotational, and gravitational speeds but are large enough to suggest that L1544 is very close to forming a star.

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Preprint available at: http://cfa–www.harvard.edu/∼jpw/papers.html

ISO–LWS detection of the 112 μm HD J=1→0 line toward the Orion Bar

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We report the first detection outside of the solar system of the lowest pure rotational J=1→0 transition of the HD molecule at 112 μm. The detection was made toward the Orion Bar using the Fabry-Pérot of the Long Wavelength Spectrometer (LWS) on board the *Infrared Space Observatory* (ISO). The line appears in emission with an integrated flux of $(0.93\pm0.17)\times10^{-19}$ W cm^{-2} in the LWS beam, implying a beam–averaged column density in the v=0, J=1 state of $(1.2\pm0.2)\times10^{17}$ cm^{-2}. Assuming LTE excitation, the total HD column density is $(2.9\pm0.8)\times10^{17}$ cm^{-2} for temperatures between 85 and 300 K. Combined with the total warm H_2 column density of $\sim (1.5-3.0)\times10^{22}$ cm^{-2} derived from either the H_2 pure rotational lines, $C^{18}O$ observations or dust continuum emission, the implied HD abundance, HD/H_2, ranges from 0.7×10^{-5} to 2.6×10^{-5}, with a preferred value of $(2.0\pm0.6)\times10^{-5}$. The corresponding deuterium abundance of [D]/[H]=$(1.0\pm0.3)\times10^{-5}$ is compared with recent values derived from ultraviolet absorption line observations of atomic H I and D I in interstellar clouds in the solar neighborhood and in Orion.

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Hot gas and dust in a protostellar cluster near W3(OH)

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We used the IRAM Interferometer to obtain sub-arcsecond resolution observations of the high-mass star-forming region W3(OH) and its surroundings at a frequency of 220 GHz. With the improved angular resolution, we distinguish 3 peaks in the thermal dust continuum emission originating from the hot core region $\approx 6''$ (0.06 pc) east of W3(OH). The dust emission peaks are coincident with known radio continuum sources, one of which is of non-thermal nature. The latter source is also at the center of expansion of a powerful bipolar outflow observed in H_2O maser emission. We determine the hot core mass to be 15 $M_\odot$ based on the integrated dust continuum emission. Simultaneously many molecular lines are detected allowing the analysis of the temperature structure and the distribution of complex organic molecules in the hot core. From HNCO lines, spanning a wide range of excitation, two 200 K temperature peaks are found coincident with dust continuum emission peaks suggesting embedded heating sources within them.

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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).

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Dissertation Abstracts

Interpreting the 10μm Astronomical Silicate Feature

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Ph.D degree awarded: November 1998

10μm spectra of silicate dust in the diffuse medium towards Cyg OB2 no. 12 and towards field and embedded objects in the Taurus Molecular Cloud (TMC) were obtained with CGS3 at the United Kingdom Infrared Telescope (UKIRT). Cold molecular-cloud silicates are sampled in quiescent lines of sight towards the field stars Taurus-Elias 16 and Elias 13, whilst observations of the embedded young stellar objects HL Tau, Taurus-Elias 7 (Haro6-10) and Elias 18 also include emission from heated dust.

To obtain the foreground silicate absorption profiles, featureless continua are estimated using smoothed astronomical and laboratory silicate emissivities. TMC field stars and Cyg OB2 no. 12 are modelled as photospheres reddened by foreground continuum and silicate extinction. Dust emission in the non-photospheric continua of HL Tau and Elias 7 (Haro6-10) is distinguished from foreground silicate absorption using a 10μm disk model, based on the IR-submm model of T Tauri stars by Adams, Lada & Shu (1988), with terms added to represent the foreground continuum and silicate extinction. The absorption profiles of HL Tau and Elias 7 are similar to that of the field star Elias 16. Fitted temperature indices of 0.43 (HL Tau) and 0.33 (Elias 7) agree with Boss' (1996) theoretical models of the 200-300K region, but are lower than those of IR-submm disks (0.5-0.61; Mannings & Emerson 1994); the modelled 10μm emission of HL Tau is optically thin, that of Elias 7 is optically thick.

A preliminary arcsecond-resolution determination of the 10μm emissivity near θ^1 Ori D in the Trapezium region of Orion and a range of emission temperatures (225-310K) are derived from observations by T. L. Hayward; this *Ney-Allen* emissivity is 0.6μm narrower than the Trapezium emissivity obtained by Forrest et al. (1975) with a large aperture.

Published interstellar grain models, elemental abundances and laboratory studies of Solar System silicates (IDPs, GEMS and meteorites), the 10μm spectra of comets, interstellar silicates, synthetic silicates and terrestrial minerals, and the effects of laboratory processing on the 10μm spectra of crystalline and amorphous silicates are reviewed to provide insight into the mineralogy of interstellar silicate dust. The wavelengths of the peaks of the 10μm silicate profiles decrease between circumstellar, diffuse medium and molecular-cloud environments, indicating (after Gürtler & Henning 1986) that the amorphous pyroxene content of initially olivine-rich interstellar dust increases with time. This is accompanied by an increase in the FWHM of the features which indicates an increase in grain size and/or an increasing fraction of chemically-varied crystalline pyroxene. Fine structure in the Cyg OB2 no. 12, Elias 16, Elias 7, HL Tau profiles indicate that hydrated layer silicates similar to terrestrial serpentines, clays and talc may be a ubiquitous component of interstellar dust. At 10μm the narrow bands of mixed crystalline pyroxenes blend, making their identification difficult. Since no fine structure is observed near 11.2μm, the fraction of crystalline olivine is small.

In geology direct olivine-plus-SiO_2 to pyroxene reactions occur only at high pressure within the terrestrial mantle. Therefore the fraction of amorphous pyroxene is probably increased by the hydration of Mg-rich olivine to form a serpentine-like hydrated silicate, which is subsequently annealed to form a mixture of amorphous pyroxene and olivine. Terrestrial and laboratory olivine samples are readily converted to serpentine in the presence of water, and (after extended annealing) the first crystalline band to appear is the 11.2μm olivine feature frequently observed in cometary spectra.

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