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Abstracts of recently accepted papers

Further evidence for the FU Orionis nature of PP 13S

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We present optical and near-IR images and spectroscopy together with sub-mm images of the candidate FU Orionis pre-main sequence star PP 13S. A comparison of historical plates to our new images shows that PP 13S has dimmed and changed optical morphology significantly over the last half century. In addition, its optical spectrum has undergone dramatic changes over a period of 18 years from one dominated by strong continuum emission to one showing only ionised, shock-excited emission lines. The current association with several features indicative of both accretion and outflow suggests that, within the last few hundred years, PP 13S passed through an elevated emission state characteristic of the high accretion events of known FU Orionis type stars, and has since declined, over the last few decades, to a more quiescent state. The result of the outburst may well have been the formation of the shock-excited Herbig-Haro jet seen to extend from the obscured young star.

We additionally see significant morphological evolution to the source PP 13N. Its apparent association with a Herbig-Haro flow suggests it also is actively accreting and driving a bipolar outflow.

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ftp://ftp.gemini.edu/pub/staff/caa/pp13s_accepted.ps.gz

The formation and evolution of binary systems. III. Low-mass binaries in the Praesepe cluster.

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With the aim of investigating the binary population of the 700 Myr old Praesepe cluster, we have observed 149 G and K-type cluster members using adaptive optics. We detected 26 binary systems with an angular separation ranging from less than 0.08 to 3.3 arcsec (15–600 AU). After correcting for detection biases, we derive a binary frequency (BF) in the logP (days) range from 4.4 to 6.9 of 25.3±5.4%, which is similar to that of field G-type dwarfs (23.8%, Duquennoy & Mayor 1991). This result, complemented by similar ones obtained for the 2 Myr old star forming cluster IC 348 (Paper II) and the 120 Myr old Pleiades open cluster (Paper I), indicates that the fraction of long-period binaries does not significantly evolve over the lifetime of galactic open clusters.

We compare the distribution of cluster binaries to the binary populations of star forming regions, most notably Orion and Taurus, to critically review current ideas regarding the binary formation process. We conclude that it is still unclear whether the lower binary fraction observed in young clusters compared to T associations is purely the result of the early dynamical disruption of primordial binaries in dense clusters or whether it reflects intrinsically different modes of star formation in clusters and associations. We also note that if Taurus binaries result from the dynamical decay of small-N protostellar aggregates, one would predict the existence of a yet to be found *dispersed* population of mostly single substellar objects in the Taurus cloud.

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Far-infrared dust opacity and visible extinction in the Polaris Flare

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We present an extinction map of the Polaris molecular cirrus cloud derived from star counts and compare it with the Schlegel et al. (1998) extinction map derived from the far–infrared dust opacity. We find that, within the Polaris cloud, the Schlegel et al. (1998) A_V values are a factor 2 to 3 higher than the star count values. We propose that this discrepancy results from a difference in $\tau_{\rm FIR}/A_V$ between the diffuse atomic medium and the Polaris cloud. We use the difference in spectral energy distribution, *warm* for the diffuse atomic medium, *cold* for the Polaris cloud, to separate their respective contribution to the line of sight integrated infrared emission and find that the $\tau_{\rm FIR}/A_V$ of *cold* dust in Polaris is on average 4 times higher than the Schlegel et al. (1998) value for dust in atomic cirrus. This change in dust property could be interpreted by a growth of fluffy particles within low opacity molecular cirrus clouds such as Polaris. Our work suggests that variations in dust emissivity must be taken into account to estimate A_V from dust emission wherever *cold* infrared emission is present (i.e. molecular clouds).

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Three-Dimensional MHD Simulations of Radiatively Cooling, Pulsed Jets

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We here investigate, by means of fully three-dimensional (3-D) Smoothed Particle Magnetohydrodynamic (SPMHD) numerical simulations, the effects of different initial magnetic field configurations on the evolution of overdense, radiatively cooling, pulsed jets, using different initial magnetic field topologies: (i) a longitudinal, (ii) a helical geometry permeating both the jet and the ambient medium, and (iii) a purely toroidal geometry permeating the jet only. We explore the effects of different pulsational periods, as well as different values of the magnetic field strength ($\beta \simeq 0.1-\infty$, or $B \simeq 260$ μG-0). The presence of a helical or a toroidal field tends to affect more the global characteristics of the fluid than a longitudinal field. However, the relative differences which have been previously detected in 2-D simulations involving distinct magnetic field configurations are diminished in the 3-D flows. While the presence of toroidal magnetic components can modify the morphology close to the jet head inhibiting its fragmentation in the early evolution of the jet, as previously reported in the literature, the impact of the pulsed-induced internal knots causes the appearance of a clumpy, complex morphology at the jet head (as required by the observations of Herbig-Haro jets) even in the MHD jet models with helical or toroidal configurations. The detailed structure and emission properties of the internal working surfaces can be also significantly altered by the presence of magnetic fields. The increase of the magnetic field strength (decrease of β) improves the jet collimation, and amplifies the density (by factors up to 1.4, and 4) and the Hα intensity (by factors up to 4, and 5) behind the knots of jets with helical field and $\beta \simeq 1 - 0.1$ (respectively), relative to a non-magnetic jet. As a consequence, the corresponding $I_{[\text{S II}]}/I_{\text{H}\alpha}$ ratio (which is frequently used to determine the excitation level of HH objects) can be decreased in the MHD models with toroidal components relative to non-magnetic calculations by about the same amounts, although the intensity estimates above are very approximate. We also find that the helical mode of the Kelvin-Helmholtz instability can be triggered in MHD models with helical magnetic fields, causing some wiggling of the jet axis. No evidence for the formation of the nose cones that are commonly detected in 2-D jet simulations with initial toroidal magnetic fields, is found in the 3-D flows, nor even in the $\beta \simeq 0.1$ case. The implications of our results for Herbig-Haro jets are briefly discussed.

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New low-mass pre-main sequence spectroscopic binaries in Orion

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We report the results of a high-resolution spectroscopic monitoring campaign on low-mass pre-main sequence spectroscopic binaries, discovered recently in the general direction of the Orion star-forming region, based on ROSAT all-sky survey X-ray observations. Also included in the present study are two binaries recognized in the course of optical follow-up observations of X-ray sources in a selected sky strip crossing the Orion SFR perpendicular to the galactic plane. Orbital elements for six double-lined spectroscopic binaries are derived from the analysis of the radial velocities of the components. The orbital periods span from 3 to 47 days. In addition, through a matching of the binary composite spectrum with synthetic binary spectra, we estimate spectral types and luminosity ratios for the components and derive lithium abundances for individual binary components. Using the estimated stellar parameters combined with kinematical information and lithium abundance determinations, we examine the evolutionary status of the objects. We then use the minimum masses derived from the solution of the spectroscopic orbits for the systems of confirmed PMS nature to make comparisons with current theoretical pre-main sequence evolutionary tracks, and attempt to set constraints on some of the most frequently used models.

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Near-IR echelle spectroscopy of Class I protostars: Molecular Hydrogen Emission-Line (MHEL) regions revealed.

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Infra-red echelle spectra are used to trace dynamic activity in the immediate vicinity of Class I outflow sources. The H_2 and Brγ observations presented here trace different components of these emission-line regions; indeed, they are thought to trace the orthogonal processes of outflow and infall respectively.

High-velocity H_2 emission is detected in the extended lobes of nine outflows. In addition, complex H_2 line emission is observed *within a few hundred AU of nine of the outflow sources.* We refer to these H_2 emission regions as "Molecular Hydrogen Emission-Line" regions, or MHELs, and compare their properties to those of Forbidden Emission-Line regions (FELs) observed in classical T Tauri and some Herbig AeBe stars. Like the FELs, both low and high-velocity components (LVC and HVC) are observed in H_2, with blue-shifted velocities of the order of 5-20 km s^{-1} and 50-150 km

s^{-1} respectively. LVCs are more common than HVCs in MHEL regions, and like their FEL counterparts, the latter are spatially further offset from the exciting source in each case. The MHEL regions – which are in all cases preferentially blue-shifted – are assumed to be associated with the base of each outflow.

Brγ profiles are detected towards four of the Class I sources observed (SVS 13, IRAS 04239+2436, HH 34-IRS and GGD 27(1)) as well as towards the T Tauri star AS 353A. These lines are all broad and symmetric, the line peaks being blueshifted by $\sim 30\,\mathrm{km\ s^{-1}}$. The profiles are typical of the permitted hydrogen line profiles observed in many T Tauri stars, and probably derive from magnetospheric accretion flows. We do not observe red-shifted absorption features (Inverse P-Cygni profiles) in any of the sources, however. Nor do we detect a dependence on line width with inclination angle of the system to the line of sight, as is predicted by such accretion models. No Brγ is detected in the extended flow lobes. Instead, the emission is confined to the source and is spatially unresolved along each flow axis.

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Postscript file available from http://www.jach.hawaii.edu/~cdavis/papers.html

Is β Pictoris an Active Star?

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We present the first emission line spectrum of β Pictoris, as revealed by the *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) satellite. Broad emission lines due to highly ionized species, C III and O VI , are well detected above the very low continuum level. The mere presence of such lines in β Pictoris spectrum is evidence of a complex stellar environment, including dense and hot regions. We argue that these spectral features may originate from a solar-like extended chromosphere or from magnetospheric accretion.

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Passive irradiated circumstellar disks with an inner hole

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A model for irradiated dust disks around Herbig Ae stars is proposed. The model is based on the flaring disk model of Chiang & Goldreich (1997), but with the central regions of the disk removed. The inner rim of the disk is puffed up and is much hotter than the rest of the disk, because it is directly exposed to the stellar flux. If located at the dust evaporation radius, its reemitted flux produces a conspicuous bump in the SED which peaks at 2–3 micron. We propose that this emission is the explanation for the near-infrared bump observed in the SEDs of Herbig Ae stars. We study for which stellar parameters this bump would be observable, and find that it is the case for Herbig Ae stellar parameters but not for T-Tauri stars, confirming what is found from the observations. We also study the effects of the shadow cast by the inner rim over the rest of the flaring disk. The shadowed region can be quite large, and under some circumstances the entire disk may lie in the shadow. This shadowed region will be much cooler than an unshadowed flaring disk, since its only heating sources are radial radiative diffusion and possible indirect sources of irradiation. Under certain special circumstances the shadowing effect can suppress, or even completely eliminate, the 10 micron emission feature from the spectrum, which might explain the anomalous SEDs of some isolated Herbig Ae stars in the sample of Meeus et al. (2001). At much larger radii the disk emerges from the shadow, and continues as a flaring disk towards the outer edge. The emission from the inner rim contributes significantly to the irradiation of this flaring disk. The complete semi-analytical model, including structure of the inner edge, shadowed region and the

flared outer part, is described in detail in this paper, and we show examples of the general behavior of the model for varying parameters.

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An interferometric study of the HH 288 molecular outflow

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We present an interferometric study of the CO J = 1 → 0 line emission in the HH 288 molecular outflow. The IRAM Plateau de Bure interferometer was used to obtain an 11–field mosaic covering the whole flow (∼2 pc) with an angular resolution of about 3.5″ (7000 AU at a distance of 2 kpc). The data were complemented with short-spacings derived from IRAM 30–m observations. The exciting source of HH 288, IRAS 00342+6347, is a young (dynamical age of the outflow $\simeq$ a few 10^4 years) intermediate-mass (bolometric luminosity $\simeq 500\ L_\odot$, envelope mass $\simeq$ 6 to 30 $M_\odot$) embedded protostar. This source is likely to be an intermediate-mass counterpart of a classical Class 0 low-mass protostar. HH 288 is actually a quadrupolar outflow, and the angular resolution provided by the interferometric observations allows us to rule out models involving limb-brightened walls of a wide-angle single flow to explain such a morphology. The presence of two protostars in the central condensation is the most appealing explanation to account for the presence of the two flows. While the small East-West flow has a quite simple morphology and kinematics, the large North-South flow includes several overlapping structures, created by successive ejection events. Large collimated limb-brightened cavities are observed, with high-velocity material located along or near the flow axis. The internal structure of HH 288, including morphological coincidence between the CO and H_2 emission, supports prompt entrainment at the head of large bow-shocks as the main formation process of molecular outflows from intermediate-mass protostars.

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Preprint available at: `http://iram.fr/papers/`

Observations of the Ionized, Neutral, and Molecular Components Associated with an Expanding HII Region

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We present H92α, HI 21 cm, NH_3 (1,1) and NH_3 (2,2) lines and radio continuum observations toward the compact HII region G111.61+0.37, located in the region Sharpless 159. The dense molecular gas (traced by the ammonia lines) in the vicinity of G111.61+0.37 is distributed in clumps indicating considerable inhomogeneity in the molecular gas. A warm (T_{rot}=47 K) ammonia clump is located just in front of the head of the cometary HII region. The photodissociated region associated to this compact HII region was detected in the HI 21 cm line. The neutral region is extended in the direction opposite to the dense molecular gas. The velocity distribution of the neutral gas suggests that the HI region is expanding in a champagne flow resembling that of the HII region, although with much lower velocities.

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http://www.astrosmo.unam.mx/˜luisfr/publ.html

The spectral energy distribution of self-gravitating protostellar disks

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The long wavelength emission of protostellar objects is commonly attributed to a disk of gas and dust around the central protostar. In the first stages of disk accretion or in the case of high mass protostars, the disk mass is likely to be sufficiently large, so that the disk self-gravity may have an impact on the dynamics and the emission properties of the disk. In this paper we describe the spectral energy distribution (SED) produced by a simple, non-flaring, self-gravitating accretion disk model. Self-gravity is included in the calculation of the rotation curve of the disk and in the energy balance equation, as a term of effective heating related to Jeans instability. In order to quantify in detail the requirements on the mass of the disk and on the accretion rate posed on the models by realistic situations, we compare the SEDs produced by these models with the observed SEDs of a small sample of well-studied protostellar objects. We find that relatively modest disks - even lighter than the central star - can lead to an interesting fit to the infrared SED of the FU Orionis objects considered, while in the case of T Tauri stars the required parameters fall outside the range suggested as acceptable by the general theoretical and observational scenario. On the basis of the present results, we may conclude that the contribution of a self-gravitating disk is plausible in several cases (in particular, for FU Orionis objects) and that, in the standard irradiation dominated disk scenario, it would help softening the requirements encountered by Keplerian accretion models.

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Secular interactions between inclined planets and a gaseous disk

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In a planetary system, a secular particle resonance occurs at a location where the precession rate of a test particle (e.g. an asteroid) matches the frequency of one of the precessional modes of the planetary system. We investigate the secular interactions of a system of mutually inclined planets with a gaseous protostellar disk that may contain a secular nodal particle resonance. We determine the normal modes of some mutually inclined planet-disk systems. The planets and disk interact gravitationally, and the disk is internally subject to the effects of gas pressure, self-gravity, and turbulent viscosity. The behavior of the disk at a secular resonance is radically different from that of a particle, owing mainly to the effects of gas pressure. The resonance is typically broadened by gas pressure to the extent that global effects, including large-scale warps, dominate. The standard resonant torque formula is invalid in this regime. Secular interactions cause a decay of the inclination at a rate that depends on the disk properties, including its mass, turbulent viscosity, and sound speed. For a Jupiter-mass planet embedded within a minimum-mass solar nebula having typical parameters, dissipation within the disk is sufficient to stabilize the system against tilt growth caused by mean-motion resonances.

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Molecular Gas in NGC 7129

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This paper reports new submillimeter molecular line observations of NGC 7129, a reflection nebula and star-forming region. Maps of ^{12}CO and ^{13}CO $2-1$ and $3-2$ emission show a cavity surrounded by bright ridges of denser molecular gas. Known molecular outflows in the region issue from deeply embedded sources in these ridges. Only the red lobe of the most prominent outflow is seen clearly, but there is some evidence to suggest that a blue counterjet is escaping through the front of the cavity. We suggest a picture of the region's evolution in which the oldest star, BD $+65°$ 1638, created the cavity by sweeping the surrounding interstellar gas into the surrounding ridges. This led to further star formation, as evidenced by the outflow sources found in the ridges. One of these sources, FIRS 2, thought to be an intermediate-mass analog of a Class 0 young stellar object, is coincident with a point-like source seen in a near-IR (K') image.

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Late-type stars members of young stellar kinematic groups – I. Single stars

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This is the first paper of a series aimed at studying the properties of late-type stars members of young stellar kinematic groups. We concentrate our study on classical young moving groups as: Local Association (Pleiades moving group, 20 - 150 Myr), IC 2391 supercluster (35 Myr), Ursa Major group (Sirius supercluster, 300 Myr), and Hyades supercluster (600 Myr); as well as on recently identified groups as: Castor moving group (200 Myr). In this paper we have compiled a preliminary list of single late-type stars possible members of some of these young stellar kinematic groups. Stars have been selected from previously established members of stellar kinematic groups based on photometric and kinematic properties as well as from candidates based on other criteria as their level of chromospheric activity, rotation rate, lithium abundance. Precise measurements of proper motions and parallaxes taken from Hipparcos Catalogue, as well as from Tycho-2 Catalogue, and published radial velocity measurements are used to calculate the Galactic space motions (U, V, W) and to apply the Eggen's kinematic criteria in order to determine the membership of the selected stars to the different groups. Additional criteria using age-dating methods for late-type stars will be applied in forthcoming papers of this series. A further study of the list of stars compiled here could lead to a better understanding of the chromospheric activity and their age evolution as well as of the star formation history in the solar neighbourhood. In addition, these stars are also potential search targets for direct imaging detection of sub-stellar companions

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http://www.ucm.es/info/Astrof/skg/skg_catalogue.html

Periodic variations in the colours of the classical T Tauri star RW Aur A

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The classical T Tauri star RW Aur A is an irregular variable with a large amplitude in all photometric bands. In an extended series of photometric data we found small-amplitude periodic variations in the blue colours of the star, with a period of 2.64 days. The period was relatively stable over several years. The amplitude of the periodic signal is $0.^{m}21$ in U–V, $0.^{m}07$ in B–V, and about $0.^{m}02$ in V–R and V–I. No periodicity was found in the V magnitude. The relevance of this photometric period to the recently discovered periodicity in spectral features of the star is discussed, and the hypothesis of a hot spot is critically considered.

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The Formation of Molecular Clouds

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In a recent paper, Elmegreen (2000) has made a cogent case, from an observational point of view, that the lifetimes of molecular clouds are comparable to their dynamical timescales. If so, this has important implications for the mechanisms by which molecular clouds form. In particular we consider the hypothesis that molecular clouds may form not by *in situ* cooling of atomic gas, but rather by the agglomeration of the dense phase of the interstellar medium (ISM), much, if not most, of which is already in molecular form.

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Modified rate equations revisited. A corrected treatment for diffusive reactions on grain surfaces

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It is well known that the rate equations for diffusive reactions on grain surfaces can be inappropriate under certain circumstances because they do not take the discrete nature of grains into account. A previous modification of the rate equations developed by us to treat surface chemistry on grains more accurately contains an error in the probability of evaporation from grain surfaces. With the rate of evaporation handled correctly, we show for a simple system in which only O and H atoms accrete on grain surfaces and react to form H_2, OH, and O_2 that the modified rate method is in reasonable agreement with a corrected Monte Carlo approach through 20 K and in excellent agreement with a new master equation approach at 10 K.

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http://www.arcetri.astro.it/∼starform/publ2001.htm

H_2 and CO emission from disks around T Tauri and Herbig Ae pre-main-sequence stars and from debris disks around young stars: warm and cold circumstellar gas

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We present ISO Short-Wavelength-Spectrometer observations of H_2 pure-rotational line emission from the disks around low and intermediate mass pre-main-sequence stars as well as from young stars thought to be surrounded by debris disks. The pre-main-sequence sources have been selected to be isolated from molecular clouds and to have circumstellar disks revealed by millimeter interferometry. We detect 'warm' ($T \approx 100-200$ K) H_2 gas around many sources, including tentatively the debris-disk objects. The mass of this warm gas ranges from $\sim 10^{-4}$ $M_\odot$ up to $8{\times}10^{-3}$ $M_\odot$, and can constitute a non-negligible fraction of the total disk mass. Complementary single-dish ^{12}CO 3–2, ^{13}CO 3–2 and ^{12}CO 6–5 observations have been obtained as well. These transitions probe cooler gas at $T \approx$ 20–80 K. Most objects show a double-peaked CO emission profile characteristic of a disk in Keplerian rotation, consistent with interferometer data on the lower-J lines. The ratios of the ^{12}CO 3–2/^{13}CO 3–2 integrated fluxes indicate that ^{12}CO 3–2 is optically thick but that ^{13}CO 3–2 is optically thin or at most moderately thick. The ^{13}CO 3–2 lines have been used to estimate the cold gas mass. If a H_2/CO conversion factor of 1×10^4 is adopted, the derived cold gas masses are factors of 10–200 lower than those deduced from 1.3 millimeter dust emission assuming a gas/dust ratio of 100, in accordance with previous studies. These findings confirm that CO is not a good tracer of the total gas content in disks since it can be photodissociated in the outer layers and frozen onto grains in the cold dense part of disks, but that it is a robust tracer of the disk velocity field. In contrast, H_2 can shield itself from photodissociation even in low-mass 'optically thin' debris disks and can therefore survive longer. The warm gas is typically 1–10 % of the total mass deduced from millimeter continuum emission, but can increase up to 100% or more for the debris-disk objects. Thus, residual molecular gas may persist into the debris-disk phase. No significant evolution in the H_2, CO or dust masses is found for stars with ages in the range of 10^6–10^7 years, although a decrease is found for the older debris-disk star β Pictoris. The large amount of warm gas derived from H_2 raises the question of the heating mechanism(s). Radiation from the central star as well as the general interstellar radiation field heat an extended surface layer of the disk, but existing models fail to explain the amount of warm gas quantitatively. The existence of a gap in the disk can increase the area of material influenced by radiation. Prospects for future observations with ground- and space-borne observations are discussed.

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^{13}C I in High-mass Star-forming Cloud

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We report measurements of the ^{12}C/^{13}C abundance ratio in the three galactic regions G 333.0-0.4, NGC 6334 A and G 351.6-1.3 from observations of the ^{12}C I $^3P_2 \rightarrow {}^3P_1$ transition and the hyperfine components of the corresponding ^{13}C I transition near 809 GHz. These transitions were observed simultaneously with the CO 7–6 line emission at 806 GHz with the AST/RO telescope located at the South Pole. From a simultaneous fit to the ^{12}C I $^3P_2 \rightarrow {}^3P_1$ transition and the HF components of the corresponding ^{13}C I transition and an independent estimate of an upper limit to the optical depth of the ^{12}C I emission we determine intrinsic ^{12}C I/^{13}C I column density ratios of 23 ± 1 for G 333.0-0.4, 56 ± 14 for NGC 6334 A and 69 ± 12 for G 351.6-1.3. As the regions observed are photon dominated, we argue that the apparent enhancement in the abundance of ^{13}C towards G 333.0-0.4 may be due to strong isotope-selective photodissociation of ^{13}CO, outweighing the effects of chemical isotopic fractionation as suggested by models of PDRs. Towards NGC 6334 A and G 351.6-1.3 these effects appear to be balanced, similar to the situation for the Orion Bar region observed by Keene et al. (1998).

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Discovery of linear "building-blocks" of water masers shaping linear/arcuate microstructures in Cepheus A

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We report three epochs of VLBA water maser observations toward the radio jet Cepheus A HW2. The VLBA data show that some of the masers detected previously with the VLA unfold into unexpected and remarkable linear/arcuate "microstructures", revealing, in particular: three filaments (R1, R2, R3) with length sizes $\simeq$ 3-25 mas (2-18 AU) and unresolved in the perpendicular direction (*leq* 0.1 AU), an arcuate structure (R4-A) of $\simeq$ 20 mas size (15 AU), and a curved chain of masers (R5; which we have previously reported) of $\simeq$ 100 mas size ($\simeq$ 72 AU). Some of these structures unfold into even smaller linear "building-blocks" (down to scales of 0.4 AU) shaping the "larger" structures. The flattened appearance of these small pieces argues strongly for a shock nature. Both the morphology and the observed proper motions found in these water maser structures have allowed us to identify at least three different centers of star formation activity in a region of $\simeq$ 300 mas (200 AU) projected radius, unknown previously, and that could constitute a triple star system. We suggest that R1, R2, and R3, which are located close to the HW2 radio jet, but offset by $\simeq$ 200 mas with respect to its axis, could originate at the shocked walls of an inner cavity excavated by the HW2 wind in the circumstellar molecular gas. The presence of a wide angle wind associated with the central HW2 object is implied. We also propose that the arcuate structure R4-A corresponds to a bow-shock structure produced by the wind of an undetected protostar (that we predict to be located toward the southeast of R4-A, $\simeq$ 200 mas south from HW2). Finally, the third energy source of this small region would be that one exciting the arc R5 which, as we have previously reported, is expanding and related to an unidentified protostar located $\simeq$ 600 mas south of HW2. The flux density of the water masers of the R5 arc excited by this unknown protostar ($\sim$ 500 Jy) represents an important fraction ($\sim$ 50%) of the total flux density of the maser emission in the entire Cepheus A star-forming region, suggesting that the exciting object could be a high-mass star. Furthermore, we find that the center of the circle which fit the R5 arc structure for each epoch, is moving with a velocity of $\sim$ 6 km s^{-1}. This could be due to proper motions of the associated protostar due to relative orbital motions within the triple star system formed by HW2 and the energy sources of the R4-A and R5 structures.

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Modelling submillimetre spectra of the protostellar infall candidates NGC1333–IRAS2 and Serpens SMM4

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We present a radiative transfer model, which is applicable to the study of submillimetre spectral line observations of protostellar envelopes. The model uses an exact, non-LTE, spherically symmetric radiative transfer 'Stenholm' method, which numerically solves the radiative transfer problem by the process of 'Λ-iteration'. We also present submillimetre spectral line data of the Class 0 protostars NGC1333–IRAS2 and Serpens SMM4. We model the data using the Stenholm code.

We examine the physical constraints which can be used to limit the number and range of parameters used in protostellar envelope models, and identify the turbulent velocity and tracer molecule abundance as the principle sources of uncertainty in the radiative transfer modelling. We explore the trends in the appearance of the predicted line profiles as key parameters in the models are varied, such as infall velocity profile, turbulence and rotation. The formation of the characteristic asymmetric double-peaked line profile in infalling envelopes is discussed. *We find that the separation of the two peaks of a typical infall profile is dependent not on the evolutionary status of the collapsing protostar, but on the turbulent velocity dispersion in the envelope.* We also find that the line shapes can be significantly altered by rotation.

Fits are found for the observed line profiles of IRAS2 and SMM4 using plausible infall model parameters. The density and velocity profiles in our best fit models are inconsistent with a singular isothermal sphere model (SIS), since for both objects modelled, the infall velocities appear further advanced than a SIS model would predict, given the density profile. We find better agreement with a form of collapse which assumes non-static initial conditions in agreement with other recent findings. We also find some evidence that the infall velocities are retarded from free-fall towards the centre of the cloud, probably by rotation, and that the envelope of SMM4 is rotationally flattened.

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The dust temperature distribution in prestellar cores

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We have computed the dust temperature distribution to be expected in a pre–protostellar core in the phase prior to the onset of gravitational instability. We have done this in the approximation that the heating of the dust grains is solely due to the attenuated external radiation field and that the core is optically thin to its own radiation. This permits us to consider non spherically symmetric geometries. We predict the intensity distributions of our model cores at millimeter and sub–millimeter wavelengths and compare with observations of the well studied object L1544. We have also developed an analytical approximation for the temperature at the center of spherically symmetric cores and we compare this with the numerical calculations. Our results show (in agreement with Evans et al. 2001) that the temperatures in the nuclei of cores of high visual extinction (> 30 magnitudes) are reduced to values of below ~ 8 K or roughly half of the surface temperature. This has the consequence that maps at wavelengths shortward of 1.3 mm see predominantly the low density exterior of pre–protostellar cores. It is extremely difficult to deduce the true density distribution from such maps alone. We have computed the intensity distribution expected on the basis of the models of Ciolek & Basu (2000) and compared with the observations of L1544. The agreement is good with a preference for higher inclinations (37° instead of 16°) than that adopted by Ciolek & Basu (2000). We find that a simple extension of the analytic approximation allows a reasonably accurate calculation of the dust temperature as a function of radius in cores with density distributions approximating those expected for Bonnor–Ebert spheres and suggest that this may be a useful tool for future calculations of the gas temperature in such cores.

Accepted by Astronomy & Astrophysics

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Dissertation Abstracts

Aperture Synthesis Studies of the Chemical Composition of Protoplanetary Disks and Comets

Chunhua Qi

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Ph.D dissertation directed by: Geoffrey A. Blake

Ph.D degree awarded: June 2001

Improvements in observational methods have now made it possible to directly observe planet-forming environments around young stars and to better characterize the most primitive relics of planetary growth in our own solar system. This thesisdescribes one such method, aperture synthesis imaging using the Owens Valley Radio Observatory (OVRO) Millimeter Array, and its application to the chemical composition of circumstellar accretion disks and comets.

The observations presented in this thesis concentrate on $\lambda \sim 3$ mm transitions of HCN/HCO^+ and $^{13}CO/CN$ in LkCa 15, GM Aur, MWC 480, and HD 163296. These disks were chosen based on their large spatial extent, Keplerian kinematic patterns, and strong CO emission. Even at a resolution of $2''$ (or a linear scale of $\sim$300 AU at the distance of Taurus and Ophiuchus), the OVRO observations show that the chemistry in circumstellar disks is sensitive to both the central stellar luminosity and the degree of dust settling toward the disk midplane. Abundance ratios such as CN/HCN and HCO^+/CO serve as unique probes of pivotal processes such as photoevaporation or cosmic ray induced ionization. The observed lower limit to the fractional ionization of 10^{-10} is sufficient to support magnetorotational instabilities that are likely to dominate the transport mechanisms in the outer reaches of protoplanetary disks. CN/HCN gradients in the T Tauri and Herbig Ae star disks appear to be correlated with the local UV radiation field and with the degree of dust settling as judged by recent fits to their spectral energy distributions, illustrating the important role of photochemistry at large disk radii. The disk emission toward LkCa 15 is particularly intense, with many molecules being detected, including HCN/HCO^+ and their ^{13}C-isotopomers, DCN, CN, HC_3N, CH_3OH, CS, ^{13}CO, and $C^{18}O$. The overall abundance patterns are consistent with recent models of photon-dominated chemistry in the near surface regions of flaring circumstellar disks that also provide a natural explanation for the mid- and far-infrared properties of the disk spectral energy distribution.

Direct ties between accretion disks and the formation of planetary systems can be tested by examining primitive solar system bodies such as comets. Comet Hale-Bopp was observed at OVRO from 1997 March 29 to April 2 in a variety of spectroscopic settings between 3.4 and 1.2 mm. The resulting aperture synthesis millimeter-wave continuum and molecular line images reveal in great detail the inner coma. The millimeter-wave continuum brightness of Hale-Bopp is dominated by emission from dust grains in the coma. By subtracting a spherically symmetric coma model from the continuum visibilities, the millimeter-wave flux from the nucleus has been isolated, and leads to an estimated radius of 19-22.5 km. The large size of comet Hale-Bopp accounts for its extraordinary outgassing rates, which permitted the aperture synthesis observations of over 18 millimeter transitions of HCN, DCN, HDO, HC_3N, HNC, HNCO, CS, H_2S, SO, OCS, CO, CH_3OH and CH_3OCH_3. The OVRO Millimeter Array was able to image, for the first time, molecular analogs of the dust jets commonly observed at optical and infrared wavelengths. This is particularly significant for investigating the true composition of comets, since jets are known to lift off large, icy grains from which direct sublimation can occur as they are exposed to the Sun. The production rates derived from the aperture synthesis images are similar to those found by other researchers, and reveal a marked similarity between the composition of Hale-Bopp and that derived for dense molecular clouds, in particular the hot cores observed near massive young stars. In addition, quite substantial D/H fractionations, comparable to the OVRO DCN/HCN measurement in LkCa 15, are found in the jets. While this clearly suggests an evolutionary history in which cometary materials remain at very low temperatures throughout their assemblage and for the bulk of their lives, the complex, kinetically controlled chemistry revealed in the OVRO images of the cold, outer regions of disks around young stars means that it is difficult to characterize cometary volatiles as being primarily “interstellar” or “nebular” in origin.

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The Arcetri Astrophysical Observatory (Florence) intends to award one post-doctoral fellowship in the field of star formation and the physics of the interstellar medium, with particular interest on applications to the scientific prospects of the ALMA (Atacama Large Millimeter Array) project. Applicants must have a Ph.D. or equivalent.

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The gross yearly salary will be between 20,000 and 25,000 Euro. The fellowship will be granted for two years (subject to an evaluation performance after the first year). The fellowship will not entail social benefits or medical insurance: each fellow will be requested to cover himself/herself with basic medical insurance. No special application forms are required. The applicants should send a CV and a list of publications to the above submission address and should arrange for two letters of recommendation to be sent directly to the same address. Applications should arrive in Arcetri no later than September 15, 2001. The starting date is January 2002, but different dates can be considered.

Application deadline: September 15, 2001

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Firenze, June 18, 2001

New Books

Very Low-Mass Stars and Brown Dwarfs

Editors R. Rebolo & M.R. Zapatero-Osorio

These are the proceedings of a meeting held in La Palma May 11-15, 1998. The study of the very low-mass end of the Mass Function has seen major developments in just the few years since the discovery of brown dwarfs, and is one of the fastest developing fields in contemporary astrophysics. This book discusses the photometric, spectroscopic, and astrometric techniques used to find brown dwarfs, and provides an overview of our understanding of the evolution and diverse properties of these very low-mass objects from both an observational as well as a theoretical point of view.

The book contains the following articles

I. Searches in Clusters, Stellar Associations and the Field
Open Clusters after HIPPARCOS J.C. Mermilliod
Proper Motions of Very Low Mass Stars and Brown Dwarfs in Open Clusters N.C. Hambly
Parallaxes for Brown Dwarfs in Clusters C.G. Tinney
Very Low Mass Stars and Brown Dwarfs in the Belt of Orion S.J. Wolk & F.M. Walter
Photometric Surveys in Open Clusters M.R. Zapatero Osorio
The Mass Function of the Pleiades R.F. Jameson et al.
Brown Dwarfs and the Low-Mass Initial Mass Function in Young Clusters K.L. Luhman
Very-Low-Mass Stars in Globular Clusters I.R. King & G. Piotto
The DENIS Very Low Mass Star and Brown Dwarf Results X. Delfosse & T. Forveille
Preliminary Results from the 2MASS Core Project J. Liebert et al.

II. Spectroscopic Properties, Fundamental Parameters and Modelling
Properties of M Dwarfs in Clusters and the Field S.L. Hawley et al.
Spectroscopy of Very Low Mass Stars and Brown dwarfs in Young Clusters E.L. Martín
High Resolution Spectra of L Type Stars and Brown Dwarfs G. Basri et al.
Modelling Very Low Mass Stars and Brown Dwarf Atmospheres F. Allard
Dust in very Cool Dwarfs T.Tsuji
On the Interpretation of the Optical Spectra of Very Cool Dwarfs Ya.V. Pavlenko et al.
Absolute Dimensions for M Type Dwarfs A. Giménez
Theory of Low Mass Stars and Brown Dwarfs; Success and Remaining Uncertainties I. Baraffe & G. Chabrier

III. Convection, Rotation and Activity
Convection in Low Mas Stars F. D'Antona
Rotation Law and Magnetic Field for M Dwarf Models G. Rüdiger & M. Küker
Doppler Imaging of Cool Stars K.G. Strassmeier
X-Ray Emission from Cool Dwarfs in Clusters S. Randich
X-ray Variability in dM Stars G. Micela & A. Marino
The Coronae of AD Leo and EV Lac S. Sciortino et al.
Prospects of Future X-ray Missions for Low Mass Stars and Cluster Stars R. Pallavicini

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Molecular Hydrogen in Space

Editors F. Combes & G. Pineau des Forêts

Molecular hydrogen is the most abundant molecule in the Universe. In recent years advances in theory and laboratory experiments coupled with breakthroughs in observations with new telescopes and satellites have revolutionized our understanding of molecular hydrogen in space. It is now possible to address the question of how molecular hydrogen formed in the early Universe and the role it played in the formation of primordial structures. This timely volume presents articles from a host of experts who reviewed this new understanding at an international conference in Paris.

The book provides the first multi-disciplinary synthesis of our new understanding of molecular hydrogen. It covers the theory of the physical processes and laboratory experiments, as well as the latest observations. It will therefore be an invaluable reference for all students and researchers in astrophysics and cosmology.

In the following are listed the invited lectures:

1. Physics of H_2 and HD

Astrophysical Importance of H_2 A. Dalgarno
Radiative and Electronic Excitation of Lyman and Werner Transitions in H_2 E. Roueff et al.
The Cooling of Astrophysical Media by H_2 and HD D. Flower et al.
Highly Excited Singlet Ungerade States of H_2 and their Theoretical Description Ch. Jungen & S.C. Ross
Laboratory Studies of Long-range Excited States of H_2 W. Ubachs
A Model of Interstellar Dark Matter J. Schaefer
Mass of H_2 Dark Matter in the Galactic Halo Y.A. Shchekinov et al.

2. Formation - Destruction

Experiments with Trapped Ions and Nanoparticles D. Gerlich et al.
Laboratory Studies of Molecular Hydrogen Formation on Surfaces of Astrophysical Interest V. Pirronello et al.
The Formation of H_2 and Other Simple Molecules on Interstellar Grains E. Herbst
The Interaction of H Atoms with Interstellar Dust Particles: Models V. Sidis et al.
The Energetics and Efficiency of H_2 Formation on the Surface of Simulated Interstellar Grains D.A. Williams et al.
Probing the Connection between PAHs and Hydrogen in the Laboratory and in the Interstellar Medium C. Joblin et al.

3. Observations and Models

Non Stationary C-shocks: H_2 Emission in Molecular Outflows G. Pineau des Forêts & D. Flower
The Ortho/Para Ratio in C- and J-type Shocks D. Wilgenbus et al.
Theoretical Models of Photodissociation Fronts B. Draine & F. Bertoldi
ISO Spectroscopy of H_2 in Star Forming Regions M.E. van den Ancker et al.
Observations of the H_2 Ortho-Para Ratio in Photodissociation Regions S. Ramsay et al.
H_2 Emission from CRL 618 F. Herpin et al.
Hydrogen in Photodissociation Regions: NGC 2023 and NGC 7023 D. Field et al.
A Pre-FUSE View of H_2 M. Jura
H_2 Absorption Line Measurements with ORFEUS P. Richter et al.
Ultraviolet Observations of Molecular Hydrogen in Interstellar Space T. Snow
FUSE and Deuterated Molecular Hydrogen R. Ferlet et al.
ISO-SWS Observations of H_2 in Galactic Sources C Wright
H_2 in Molecular Supernova Remnants W.T. Reach and J. Rho
3D Integral Field H_2 Spectroscopy in Outflows J. Tedds et al.
Near-Infrared Imaging and [OI] Spectroscopy of IC 443 using 2MASS and ISO J. Rho et al.
ISOCAM Spectro-imaging of the Supernova Remnant IC 443 P. Cox et al.
Spatial Structure of a Photo-Dissociation Region in Ophiuchus F. Boulanger et a.
Tracing H_2 Via Infrared Dust Extinction J. Alves et al.
The Small Scale Structure of H_2 Clouds P. Boissé et al.
Hot Chemistry in the Cold Diffuse Medium E. Falgarone et al.
H_2 Observations of the OMC-1 Outflow with the ISO-SWS D. Rosenthal et al.

4. Extragalactic and Cosmology

The Role of H_2 Molecules in Cosmological Structure Formation T. Abel & Z. Haiman
The Role of H_2 Molecules in Primordial Star Formation F. Palla & D. Galli
Evolution of Primordial H_2 for Different Cosmologiccal Models D. Puy
Dynamics of H_2 Cool Fronts in the Primordial Gas M. Ibanez & M. Bessega
Is Reionization Regulated by H_2 in the Early Universe A. Ferrara et al.
H_2 in Galaxies F. Combes
Transformation of Galaxies eithin the Hubble Sequence D. Pfenniger
Extragalactic H_2 and its Variable Relation to CO F.P. Israel
The Galactic Dark Matter Halo: Is it H_2? P. Kalberla et al.
Observations of H_2 in Quasar Absorbers J. Bechtold
H_2 Emission as a Diagnostic of Physical Processes in Starforming Galaxies P. van der Werf

5. Outlook

H_2 in the Universe: Perspectives J. Black

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