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Abstracts of recently accepted papers

Molecular Evolution and Star Formation: From Prestellar Cores to Protostellar Cores

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We investigate molecular evolution in a star-forming core that is initially a hydrostatic starless core and collapses to form a low-mass protostar. The results of a one-dimensional radiation-hydrodynamics calculation are adopted as a physical model of the core. We first derive radii at which CO and large organic species sublime. CO sublimation in the central region starts shortly before the formation of the first hydrostatic core. When the protostar is born, the CO sublimation radius extends to 100 AU, and the region inside $\lesssim 10$ AU is hotter than 100 K, at which some large organic species evaporate. We calculate the temporal variation of physical parameters in infalling shells, in which the molecular evolution is solved using an updated gas-grain chemical model to derive the spatial distribution of molecules in a protostellar core. The shells pass through the warm region of 10 – 100 K in several $\times 10^4$ yr, and fall into the central star ~ 100 yr after they enter the region where $T \gtrsim 100$ K. We find that large organic species are formed mainly via grain-surface reactions at temperatures of 20 – 40 K and then desorbed into the gas-phase at their sublimation temperatures. Carbon-chain species can be formed by a combination of gas-phase reactions and grain-surface reactions following the sublimation of CH₄. Our model also predicts that CO₂ is more abundant in isolated cores, while gas-phase large organic species are more abundant in cores embedded in ambient clouds.

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A Submillimeter View of Circumstellar Dust Disks in ρ Ophiuchus

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We present new multiwavelength submillimeter continuum measurements of the circumstellar dust around 48 young stars in the ρ Ophiuchus dark clouds. Supplemented with previous 1.3 mm observations of an additional 99 objects from the literature, the statistical distributions of disk masses and submillimeter colors are calculated and compared to those in the Taurus-Auriga region. These basic submillimeter properties of young stellar objects in both environments are shown to be essentially identical. As with their Taurus counterparts, the ρ Oph circumstellar dust properties are shown to evolve along an empirical evolution sequence based on the infrared spectral energy distribution. The combined ρ Oph and Taurus Class II samples (173 sources) are used to set benchmark values for basic outer disk characteristics: $M_d \sim 0.005 M_\odot$, $M_d/M_* \sim 1\%$, and $\alpha \sim 2$ (where $F_\nu \propto \nu^\alpha$ between 350 μm and 1.3 mm). The precision of these numbers are addressed in the context of substantial solid particle growth in the earliest stages of

the planet formation process. There is some circumstantial evidence that disk masses inferred from submillimeter emission may be under-estimated by up to an order of magnitude.

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NTT and VLT diffraction limited imaging of Trumpler 14: Revealing a massive core-halo cluster

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Aims We present the deepest and highest resolution near-infrared imaging to date of cluster Trumpler 14 in Carina. Our goal is to identify and characterise the young stellar population of this massive cluster. *Methods* We made use of deep and wide-field NIR images from NTT and VLT observations, that were sensitive enough to detect substellar sources at the distance to this cluster, and at high enough resolution (VLT diffraction limited) to fully resolve the core of the cluster crowded with O stars. *Results* We find that Tr14 has a well-defined core-halo structure, where less than 30% of the cluster's members reside in the core. The core is well characterised by a King function with a core radius of 0'17 (0.14 pc at the adopted distance) and a constant baseline, the halo, of 125 sources/pc². Despite the unusually large number of OB stars, the central number density at zero radius is $\sim 7.3 \times 10^3$ pc⁻³, which is loose in comparison with similar clusters. We find a normal reddening law towards the cluster and derive a global reddening of $A_v = 2.6 \pm 0.3$ mag. We find convincing evidence of a sparse foreground population (~ 5 sources/arcmin²) reddened by about $A_v = 1.4$ mag, which we suggest is not associated with Tr14 but is most likely an older population produced in the nearby young clusters of this complex. The colour-magnitude diagrams are compatible with ages between "zero" and ~ 5 Myr, although the sources from the core of the cluster appear to concentrate on the youngest isochrones, suggesting that the halo population is, on average, slightly older than the core population. Using a set of simplistic, fixed-age, mass-luminosity relations, we derive a mass of $10^4 M_\odot$ for the cluster. From the NACO JHK_sL' data, we estimate a fraction of infrared-excess sources of 35%, although this is likely to be an underestimate given the bright completeness limits of the L' band. Finally, we argue that the formerly identified proplyd candidates that fall inside our survey are not proplyds but remnants of the disrupted molecular cloud that surround the cluster. We also find a series of interesting objects in our field that are worthy of future attention: a candidate photoionised proplyd best seen in the L' band, a compact nebula surrounding an early type star, and a tentative proplyd/small shock associated with a faint source.

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<http://www.astro.up.pt/~jascenso/tr14.pdf>

Extended wind in jetless classical T Tauri star TW Hya

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We have conducted a spectro-astrometric (SA) analysis of high spectral resolution data of the near infrared HeI 10830Å and Paγ lines in the nearby classical T Tauri star TW Hya. We find clear position offsets associated to the blueshifted absorption part of the HeI 10830Å P Cygni profile. The derived spatial feature extend up to 50 mas (2.8AU at TW

Hya distance) in two opposite directions. By using simple exploratory models we show that this feature can not be produced by the same stellar wind which produces the P Cygni profile. Instead, we are able to reproduce the observed blueshifted SA profile with emission from a disk wind. The production of SA artifacts through instrumental effects was examined. Artifact models have difficulties in fitting both the PSF and the angular scale of the observed position spectra offsets, suggesting that the signal may be real.

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Post-Outburst Observations of V1647 Ori: Detection of a Brief Warm, Molecular Outflow

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We present new observations of the fundamental ro-vibrational CO spectrum of V1647 Ori, the young star whose recent outburst illuminated McNeil's Nebula. Previous spectra, acquired during outburst in 2004 February and July, had shown the CO emission lines to be broad and centrally peaked—similar to the CO spectrum of a typical classical T Tauri star. In this paper, we present CO spectra acquired shortly after the luminosity of the source returned to its pre-outburst level (2006 February) and roughly one year later (2006 December and 2007 February). The spectrum taken in 2006 February revealed blue-shifted CO absorption lines superimposed on the previously observed CO emission lines. The projected velocity, column density, and temperature of this outflowing gas was 30 km s^{-1} , $3_{-1}^{+2} \times 10^{18} \text{ cm}^{-2}$, and $700_{-100}^{+300} \text{ K}$, respectively. The absorption lines were not observed in the 2006 December and 2007 February data, and so their strengths must have decreased in the interim by a factor of 9 or more. We discuss three mechanisms that could give rise to this unusual outflow.

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Keck HIRES Spectroscopy of Candidate Post T Tauri Stars

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We use high-signal-to-noise (~ 150 -450), high resolution ($R \sim 45,000$) Keck HIRES spectroscopy of 13 candidate post T Tauri stars to derive basic physical parameters, lithium abundances and radial velocities. We place our stars in the M_v - T_{eff} plane for use in determining approximate ages from pre-main sequence isochrones, and confirm these using three relative age indicators in our analysis: Li abundances, chromospheric emission and the kinematic U - V plane. Using the three age criteria we identify 5 stars (HIP 54529, HIP 62758, HIP 63322, HIP 74045, and HIP 104864) as probable post T Tauri stars with ages between 10 and 100 Myr. We confirm HIP 54529 as an SB2 and HIP 63322 as an SB1 star. We also examine irregular photometric variability of PTTs using the *HIPPARCOS* photometry annex. Two of our PTT stars exhibit near-IR excesses compared to Kurucz model flux; while recent work suggests classical T Tauri stars evince similar *JHK* excesses presumably indicative of non-photospheric (disk) emission, our results may be illusory artifacts of the chosen *I*-band normalization. Near-IR excesses we see in a literature-based sample of PTTs

appear to be artifacts of previous spectral type-based T_{eff} values. Indeed, comparison of the homology of their observed and model photospheric SED's suggests that photometric temperatures are more reliable than temperatures based on spectral standards for the cooler temperature ranges of the stars in this sample. We conclude that our age oriented analysis is a robust means to select samples of nearby, young, isolated post T Tauri stars that otherwise masquerade as normal field stars.

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Spatial distribution of stars and brown dwarfs in σ Orionis

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I have re-visited the spatial distribution of stars and high-mass brown dwarfs in the σ Orionis cluster (~ 3 Ma, ~ 360 pc). The input was a catalogue of 340 cluster members and candidates at separations less than 30 arcmin to σ Ori AB. Of them, 70 % have features of extreme youth. I fitted the normalised cumulative number of objects counting from the cluster centre to several power-law, exponential and King radial distributions. The cluster seems to have two components: a dense core that extends from the centre to $r \approx 20$ arcmin and a rarified halo at larger separations. The radial distribution in the core follows a power-law proportional to r^1 , which corresponds to a volume density proportional to r^{-2} . This is consistent with the collapse of an isothermal spherical molecular cloud. The stars more massive than $3.7 M_{\odot}$ concentrate, however, towards the cluster centre, where there is also an apparent deficit of very low-mass objects ($M < 0.16 M_{\odot}$). Last, I demonstrated through Monte Carlo simulations that the cluster is azimuthally asymmetric, with a filamentary overdensity of objects that runs from the cluster centre to the Horsehead Nebula.

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The Thermal Regulation of Gravitational Instabilities in Protoplanetary Disks IV. Simulations with Envelope Irradiation

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It is generally thought that protoplanetary disks embedded in envelopes are more massive and thus more susceptible to gravitational instabilities (GIs) than exposed disks. We present three-dimensional radiative hydrodynamics simulations of protoplanetary disks with the presence of envelope irradiation. For a disk with a radius of 40 AU and a mass of 0.07 Msun around a young star of 0.5 Msun, envelope irradiation tends to weaken and even suppress GIs as the irradiating flux is increased. The global mass transport induced by GIs is dominated by lower-order modes, and irradiation preferentially suppresses higher-order modes. As a result, gravitational torques and mass inflow rates are actually increased by mild irradiation. None of the simulations produce dense clumps or rapid cooling by convection, arguing against direct formation of giant planets by disk instability, at least in irradiated disks. However, dense gas rings and radial mass concentrations are produced, and these might be conducive to accelerated planetary core formation. Preliminary results from a simulation of a massive embedded disk with physical characteristics similar to one of the disks in the embedded source L1551 IRS5 indicate a long radiative cooling time and no fragmentation. The GIs in this disk are dominated by global two and three-armed modes.

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Total to Selective Extinction in the Dark Globule CB 107

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We discuss optical (B, V, and I) and near-infrared (J, H, and K_s) imaging observations of the small dark cloud CB 107. The cloud is projected against a rich stellar background, making it possible to detect ~ 3900 stars in all six photometric bands. After an accurate choice of a reference region, we obtained the color excess $E_{\lambda-V}$ maps and derived the distribution of the total to selective extinction R_V across the cloud by adopting three different techniques. The R_V map obtained closely follows the optical shape of CB 107 with the value $R_V \simeq 3.1$, typical of the diffuse interstellar medium, corresponding to the optical limit of the globule. Larger values up to $R_V \sim 5$ are found in the innermost regions, indicating an increase in the dust grain mean size. On the basis of our results, the three methods adopted have been found to be almost equivalent. We also estimated the R_V values along the lines of sight of individual stars that, considered in a given spatial box, have been used to obtain both average value and dispersion, as a function of the position. A scatter plot of these two quantities shows that the dispersion σ_{R_V} increases with R_V similarly to the correlation between extinction dispersion σ_{A_V} and A_V already known in the literature. Finally, we discuss the R_V versus A_V scatter plot on the basis of a simple model that helps us to give a plausible physical interpretation of this correlation.

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CO abundances in a protostellar cloud: freeze-out and desorption in the envelope and outflow of L483

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CO isotopes are able to probe the different components in protostellar clouds. These components, core, envelope and outflow have distinct physical conditions and sometimes more than one component contributes to the observed line profile. In this study we determine how CO isotope abundances are altered by the physical conditions in the different components. We use a 3D molecular line transport code to simulate the emission of four CO isotopomers, $^{12}\text{CO } J = 2 \rightarrow 1$, $^{13}\text{CO } J = 2 \rightarrow 1$, $\text{C}^{18}\text{O } J = 2 \rightarrow 1$ and $\text{C}^{17}\text{O } J = 2 \rightarrow 1$ from the Class 0/1 object L483, which contains a cold quiescent core, an infalling envelope and a clear outflow. Our models replicate JCMT (James Clerk Maxwell Telescope) line observations with the inclusion of freeze-out, a density profile and infall. Our model profiles of ^{12}CO and ^{13}CO have a large linewidth due to a high velocity jet. These profiles replicate the process of more abundant material being susceptible to a jet. C^{18}O and C^{17}O do not display such a large linewidth as they trace denser quiescent material deep in the cloud.

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A Search for Near-Infrared Molecular Hydrogen Emission in the CTTS LkH α 264 and the debris disk 49 Ceti

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We report on the first results of a search for molecular hydrogen emission from protoplanetary disks using CRIRES, ESO's new VLT Adaptive Optics high resolution near-infrared spectrograph. We observed the classical T Tauri star LkH α 264 and the debris disk 49 Cet, and searched for $v = 1 - 0$ S(1) H $_2$ emission at 2.1218 μm , $v = 1 - 0$ S(0) H $_2$ emission at 2.2233 μm and $v = 2 - 1$ S(1) H $_2$ emission at 2.2477 μm . The H $_2$ line at 2.1218 μm is detected in LkH α 264 confirming the previous observations by Itoh et al. (2003). In addition, our CRIRES spectra reveal the previously observed but not detected H $_2$ line at 2.2233 μm in LkH α 264. An upper limit of 5.3×10^{-16} ergs s $^{-1}$ cm $^{-2}$ on the $v = 2 - 1$ S(1) H $_2$ line flux in LkH α 264 is derived. The detected lines coincide with the rest velocity of LkH α 264. They have a FWHM of ~ 20 km s $^{-1}$. This is strongly suggestive of a disk origin for the lines. These observations are the first simultaneous detection of $v = 1 - 0$ S(1) and $v = 1 - 0$ S(0) H $_2$ emission from a protoplanetary disk. 49 Cet does not exhibit H $_2$ emission in any of the three observed lines. We derive the mass of optically thin H $_2$ at $T \sim 1500$ K in the inner disk of LkH α 264 and derive stringent limits in the case of 49 Cet at the same temperature. There are a few lunar masses of optically thin hot H $_2$ in the inner disk (~ 0.1 AU) of LkH α 264, and less than a tenth of a lunar mass of hot H $_2$ in the inner disk of 49 Cet. The measured 1-0 S(0)/1-0 S(1) and 2-1 S(1)/1-0 S(1) line ratios in LkH α 264 indicate that the H $_2$ emitting gas is at a temperature lower than 1500 K and that the H $_2$ is most likely thermally excited by UV photons. The $v = 1 - 0$ S(1) H $_2$ line in LkH α 264 is single peaked and spatially unresolved. Modeling of the shape of the line suggests that the disk should be seen close to face-on ($i < 35^\circ$) and that the line is emitted within a few AU of the LkH α 264 disk. A comparative analysis of the physical properties of classical T Tauri stars in which the H $_2$ $v = 1 - 0$ S(1) line has been detected and non-detected indicates that the presence of H $_2$ emission is correlated with the magnitude of the UV excess and the strength of the H α line. The lack of H $_2$ emission in the NIR spectra of 49 Cet and the absence of H α emission suggest that the gas in the inner disk of 49 Cet has dissipated. These results combined with previous detections of ^{12}CO emission at sub-mm wavelengths indicate that the disk surrounding 49 Cet should have an inner hole. We favor inner disk dissipation by inside-out photoevaporation, or the presence of an unseen low-mass companion as the most likely explanations for the lack of gas in the inner disk of 49 Cet.

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A Search for Mid-Infrared Molecular Hydrogen Emission from Protoplanetary Disks

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We report on a sensitive search for mid-infrared molecular hydrogen emission from protoplanetary disks. We observed the Herbig Ae/Be stars UX Ori, HD 34282, HD 100453, HD 101412, HD 104237 and HD 142666, and the T Tauri star HD 319139 and searched for H $_2$ 0 - 0 S(2) ($J = 4 - 2$) emission at 12.278 micron and H $_2$ 0 - 0 S(1) ($J = 3 - 1$) emission at 17.035 micron with VISIR, ESO-VLT's high-resolution mid-infrared spectrograph. None of the sources present evidence for molecular hydrogen emission at the wavelengths observed. Stringent 3σ upper limits to the integrated line fluxes and the mass of optically thin warm gas ($T = 150, 300$ and 1000 K) in the disks are derived. The disks contain less than a few tenths of Jupiter mass of optically thin H $_2$ gas at 150 K at most, and less than a few Earth masses of optically thin H $_2$ gas at 300 K and higher temperatures. We compare our results to a Chiang and Goldreich (1997, CG97) two-layer disk model of masses $0.02 M_\odot$ and $0.11 M_\odot$. The upper limits to the disk's optically thin warm gas mass are smaller than the amount of warm gas in the interior layer of the disk, but they are much larger than the amount of molecular gas expected to be in the surface layer. If the two-layer approximation to the structure of the disk is correct, our non-detections are consistent with the low flux levels expected from the small

amount of H_2 gas in the surface layer. We present a calculation of the expected thermal H_2 emission from optically thick disks, assuming a CG97 disk structure, a gas-to-dust ratio of 100 and $T_{\text{gas}} = T_{\text{dust}}$. We show that the expected H_2 thermal emission fluxes from typical disks around Herbig Ae/Be stars are of the order of 10^{-16} to 10^{-17} $\text{erg s}^{-1} \text{cm}^{-2}$ for a distance of 140 pc. This is much lower than the detection limits of our observations (5×10^{-15} $\text{erg s}^{-1} \text{cm}^{-2}$). H_2 emission levels are very sensitive to departures from the thermal coupling between the molecular gas and dust in the surface layer. Additional sources of heating of gas in the disk’s surface layer could have a major impact on the expected H_2 disk emission. Our results suggest that in the observed sources the molecular gas and dust in the surface layer have not significantly departed from thermal coupling ($T_{\text{gas}}/T_{\text{dust}} < 2$) and that the gas-to-dust ratio in the surface layer is very likely lower than 1000.

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Mass Segregation in Very Young Open Clusters: A Case Study of NGC 2244 and NGC 6530

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We derive the proper motions, membership probabilities, and velocity dispersions of stars in the regions of the young (~ 24 Myr old) open clusters NGC 2244 (the central cluster in the Monoceros R2 association) and NGC 6530 (the dominant cluster in the Sgr OB1 association) from photographic plate material obtained at Shanghai Astronomical Observatory, with time baselines of 34 and 87 yr, respectively. Both clusters show clear evidence of mass segregation, but they do not exhibit any significant velocity-mass (or, equivalently, velocity-luminosity) dependence. This provides strong support for the suggestion that the observed mass segregation is at least partially due to the way in which star formation has proceeded in these complex star-forming regions (“primordial” mass segregation). Based on arguments related to the clusters’ published initial mass functions, in conjunction with our new measurements of their internal velocity dispersions (~ 35 and 8 km s^{-1} for NGC 2244 and NGC 6530, respectively), we provide strong arguments in favor of the dissolution of NGC 2244 on very short timescales, while we speculate that NGC 6530 may be more stable against the effects of internal two-body relaxation. However, this latter object may well be destroyed by the strong tidal field prevalent at its location in the Galactic plane in the direction of the Galactic center.

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Simulation of the Formation and Morphology of Ice Mantles on Interstellar Grains

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Although still poorly understood, the chemistry that occurs on the surfaces of interstellar dust particles profoundly affects the growth of molecules in the interstellar medium. An important set of surface reactions produces icy mantles of many monolayers in cold and dense regions. The monolayers are dominated by water ice, but also contain CO, CO_2 , and occasionally methanol, as well as minor constituents. In this paper, the rate of production of water-ice-dominated mantles is calculated for different physical conditions of interstellar clouds and for the first time images of the morphology of interstellar ices are presented. For this purpose, the continuous-time random-walk Monte Carlo simulation technique has been used. The visual extinction, density, and gas and grain temperatures are varied. It is shown that our stochastic approach can reproduce the important observation that ice mantles only grow in the denser

regions.

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The Rise and Fall of Debris Disks: MIPS Observations of η and χ Persei and the Evolution of Mid-IR Emission from Planet Formation

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We describe Spitzer/MIPS observations of the double cluster, η and χ Persei, covering a ~ 0.6 square-degree area surrounding the cores of both clusters. The data are combined with IRAC and 2MASS data to investigate ~ 616 sources from 1.25-24 μm . We use the long-baseline K_s -[24] color to identify two populations with IR excess indicative of circumstellar material: Be stars with 24 μm excess from optically-thin free free emission and 17 fainter sources ($J \sim 14$ -15) with [24] excess consistent with a circumstellar disk. The frequency of IR excess for the fainter sources increases from 4.5 μm through 24 μm . The IR excess is likely due to debris from the planet formation process. The wavelength-dependent behavior is consistent with an inside-out clearing of circumstellar disks. A comparison of the 24 μm excess population in η and χ Per sources with results for other clusters shows that 24 μm emission from debris disks 'rises' from 5 to 10 Myr, peaks at ~ 10 -15 Myr, and then 'falls' from $\sim 15/20$ Myr to 1 Gyr.

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The Excitation of N_2H^+ in Interstellar Molecular Clouds. II. Observations

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We present observations of the $J = 10$, 21, and 32 rotational transitions of N_2H^+ and N_2D^+ toward a sample of prototypical dark clouds. The data have been interpreted using nonlocal radiative transfer models. For all sources previously studied through millimeter-continuum observations, we find a good agreement between the volume density estimated from our N_2H^+ data and that estimated from the dust emission. This confirms that N_2H^+ depletion is not very efficient in dark clouds for densities as large as 10^6 cm^{-3} , and also points out that a simultaneous analysis based on millimeter-continuum, N_2H^+ and N_2D^+ observations should lead to reliable estimates for the temperature and density structure of cold dark clouds. From multiline modeling of N_2H^+ and N_2D^+ , we derive the deuterium enrichment in the observed clouds. Our estimates are similar or higher than previous ones. The differences can be explained by the assumptions made on the cloud density profile and by the chemical fractionation occurring in the clouds. For two of the observed objects, L183 and TMC 2, multiposition observations have allowed us to derive the variation of the N_2D^+/N_2H^+ abundance ratio with the radius. We have found that it decreases by an order of magnitude for radii greater than a few 0.01 pc (i.e., outside the central cores). Inside the dense condensations, the fractionation is efficient and, compared to the abundance ratio expected from statistical considerations based on the cosmic D/H ratio, the deuterium enrichment is estimated to be $\simeq (0.1 - 0.5) \times 10^5$.

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Magnetic fields and accretion flows on the classical T Tauri star V2129 Oph

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From observations collected with the ESPaDOnS spectropolarimeter, we report the discovery of magnetic fields at the surface of the mildly accreting classical T Tauri star (cTTS) V2129 Oph. Zeeman signatures are detected, both in photospheric lines and in the emission lines formed at the base of the accretion funnels linking the disc to the protostar, and monitored over the whole rotation cycle of V2129 Oph. We observe that rotational modulation dominates the temporal variations of both unpolarized and circularly polarized line profiles.

We reconstruct the large-scale magnetic topology at the surface of V2129 Oph from both sets of Zeeman signatures simultaneously. We find it to be rather complex, with a dominant octupolar component and a weak dipole of strengths 1.2 and 0.35 kG, respectively, both slightly tilted with respect to the rotation axis. The large-scale field is anchored in a pair of 2-kG unipolar radial field spots located at high latitudes and coinciding with cool dark polar spots at photospheric level. This large-scale field geometry is unusually complex compared to those of non-accreting cool active subgiants with moderate rotation rates.

As an illustration, we provide a first attempt at modelling the magnetospheric topology and accretion funnels of V2129 Oph using field extrapolation. We find that the magnetosphere of V2129 Oph must extend to about $7R_\star$ to ensure that the footpoints of accretion funnels coincide with the high-latitude accretion spots on the stellar surface. It suggests that the stellar magnetic field succeeds in coupling to the accretion disc as far out as the corotation radius, and could possibly explain the slow rotation of V2129 Oph. The magnetospheric geometry we derive qualitatively reproduces the modulation of Balmer lines and produces X-ray coronal fluxes typical of those observed in cTTSs.

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Multiple protostellar systems. II. A high resolution near-infrared imaging survey in nearby star-forming regions.

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Multiple systems are the product of protostellar core fragmentation. Studying their statistical properties in young stellar populations therefore probes the physical processes at play during star formation. Our project endeavors to obtain a robust view of multiplicity among embedded Class I and Flat Spectrum protostars in a wide array of nearby molecular clouds to disentangle “universal” from cloud-dependent processes. We have used near-infrared adaptive optics observations at the VLT through the H , K_s and L' filters to search for tight companions to 45 Class I and Flat Spectrum protostars located in 4 different molecular clouds (Taurus-Auriga, Ophiuchus, Serpens and L1641 in Orion). We complemented these observations with published high-resolution surveys of 13 additional objects in Taurus and Ophiuchus. We found multiplicity rates of $32\pm 6\%$ and $47\pm 8\%$ over the 45–1400 AU and 14–1400 AU separation ranges, respectively. These rates are in excellent agreement with those previously found among T Tauri stars in Taurus and Ophiuchus, and represent an excess of a factor ~ 1.7 over the multiplicity rate of solar-type field stars. We found no non-hierarchical triple systems, nor any quadruple or higher-order systems. No significant cloud-to-cloud difference

has been found, except for the fact that all companions to low-mass Orion protostars are found within 100 AU of their primaries whereas companions found in other clouds span the whole range probed here. Based on this survey, we conclude that core fragmentation always yields a high initial multiplicity rate, even in giant molecular clouds such as the Orion cloud or in clustered stellar populations as in Serpens, in contrast with predictions of numerical simulations. The lower multiplicity rate observed in clustered Class II and Class III populations can be accounted for by a universal set of properties for young systems and subsequent ejections through close encounters with unrelated cluster members.

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On the Diversity of the Taurus Transitional Disks: UX Tau A & Lk Ca 15

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The recently recognized class of “transitional disk” systems consists of young stars with optically-thick outer disks but inner disks which are mostly devoid of small dust. Here we introduce a further class of “pre-transitional disks” with significant near-infrared excesses which indicate the presence of an optically thick inner disk separated from an optically thick outer disk; thus, the spectral energy distributions of pre-transitional disks suggest the incipient development of disk gaps rather than inner holes. In UX Tau A, our analysis of the *Spitzer* IRS spectrum finds that the near-infrared excess is produced by an inner optically thick disk and a gap of ~ 56 AU is present. The *Spitzer* IRS spectrum of LkCa 15 is suggestive of a gap of ~ 46 AU, confirming previous millimeter imaging. In addition, UX Tau A contains crystalline silicates in its disk at radii ≥ 56 AU which poses a challenge to our understanding of the production of this crystalline material. In contrast, LkCa 15’s silicates are amorphous and pristine. UX Tau A and LkCa 15 increase our knowledge of the diversity of dust clearing in low-mass star formation.

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Water maser variability over 20 years in a large sample of star-forming regions: the complete database

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Context. Water vapor emission at 22 GHz from masers associated with star-forming regions is highly variable.

Aims. We present a database of up to 20 years of monitoring of a sample of 43 masers within star-forming regions. The sample covers a large range of luminosities of the associated IRAS source and is representative of the entire population of H₂O masers of this type. The database forms a good starting point for any further study of H₂O maser variability.

Methods. The observations were obtained with the Medicina 32-m radiotelescope, at a rate of 4–5 observations per year.

Results. To provide a database that can be easily accessed through the web, we give for each source: plots of the calibrated spectra, the velocity–time–flux density plot, the light curve of the integrated flux, the lower and upper envelopes of the maser emission, the mean spectrum, and the rate of the maser occurrence as a function of velocity. Figures for just one source are given in the text for representative purposes. Figures for all the sources are given in electronic form in the on-line appendix. A discussion of the main properties of the H₂O variability in our sample will be presented in a forthcoming paper.

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http://www.arcetri.astro.it/~starform/preprints/pap_mas.pdf

http://www.arcetri.astro.it/~starform/preprints/pap_mas_online.pdf

Candidate Rotating Toroids around High-Mass (Proto)Stars

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Using the OVRO, Nobeyama, and IRAM mm-arrays, we searched for “disk”-outflow systems in three high-mass (proto)star forming regions: G 16.59–0.05, G 23.01–0.41, and G 28.87+0.07. These were selected from a sample of NH₃ cores (Codella, Testi & Cesaroni) associated with OH and H₂O maser emission (Foster & Caswell) and with no or very faint continuum emission. Our imaging of molecular line (including rotational transitions of CH₃CN) and 3 mm dust continuum emission revealed that these are compact ($\lesssim 0.05 - 0.3$ pc), massive ($\sim 100 - 400 M_{\odot}$), and hot (~ 100 K) molecular cores (HMCs), that is likely sites of high-mass star formation prior to the appearance of ultracompact HII regions. All three sources turn out to be associated with molecular outflows from ¹²CO and/or HCO⁺ $J=1-0$ line imaging. In addition, velocity gradients of $10 - 100$ km s⁻¹ pc⁻¹ in the innermost ($\lesssim 0.03 - 0.13$ pc), densest regions of the G 23.01–0.41 and G 28.87+0.07 HMCs are identified along directions roughly perpendicular to the axes of the corresponding outflows. All the results suggest that these cores might be rotating about the outflow axis, although the contribution of rotation to gravitational equilibrium of the HMCs appears to be negligible. Our analysis indicates that the 3 HMCs are close to virial equilibrium due to turbulent pressure support. Comparison with other similar objects where rotating toroids have been identified so far shows that in our case rotation appears to be much less prominent; this can be explained by the combined effect of unfavorable projection, large distance, and limited angular resolution with the current interferometers.

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Structure of W3(OH) from Very High Spectral Resolution Observations of 5 Centimeter OH Masers

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Recent studies of methanol and ground-state OH masers at very high spectral resolution have shed new light on small-scale maser processes. The nearby source W3(OH), which contains numerous bright masers in several different transitions, provides an excellent laboratory for high spectral resolution techniques. We present a model of W3(OH) based on European VLBI Network (EVN) observations of the rotationally excited 6030 and 6035 MHz OH masers taken at 0.024 km s⁻¹ spectral resolution. The 6.0 GHz masers are becoming brighter with time and show evidence for tangential proper motions. We confirm the existence of a region of magnetic field oriented toward the observer

to the southeast and find another such region to the northeast in W3(OH), near the champagne flow. The 6.0 GHz masers trace the inner edge of a counterclockwise rotating torus feature. Masers at 6030 MHz are usually a factor of a few weaker than at 6035 MHz but trace the same material. Velocity gradients of nearby Zeeman components are much more closely correlated than in the ground state, likely due to the smaller spatial separation between Zeeman components. Hydroxyl maser peaks at very long baseline interferometric resolution appear to have structure both on scales smaller than that resolvable and on larger scales.

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Herbig-Haro flows in B335

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Aims To study the Herbig-Haro flows in the nearby dark globule B335. To find new HH objects and H₂ knots, make a proper motion map of the flow activity and investigate physical properties through shock models.

Methods We have observed optical (H α and [SII]) and near-IR (2.12 μ m H₂) deep fields and taken optical spectra using the 2.56 m Nordic Optical Telescope, as well as a near-UV deep field (*U* band) using the 3.58 m NTT. In addition we present new SPITZER/IRAC (3.5–8.0 μ m) and MIPS (24 μ m) observations. We use previous H α and 2.12 μ m H₂ observations taken 15 and 9 years earlier to make proper motion maps. We then investigate the shock physics by matching our spectra with planar shock models.

Results We discover five new HH objects (HH 119 D–H) in the eastern and one (HH 119 I) in the western lobe of the outflow. From proper motions we find an optically bright, roughly E–W oriented group with high space velocities (200–280 km s⁻¹) and a near-IR bright, slower group (15–75 km s⁻¹) moving to the ESE. We also find a system of at least 15 H₂ knots in the western lobe. This (WNW) counterflow suggests the possibility of a binary outflow source, giving rise to two outflow axes with slightly different orientations. We find that the E–W flow is symmetrical with evidence for two outbursts. We make the first detection of [OI] $\lambda\lambda$ 6300/63 in HH 119 B and H β in HH 119 A and B and find their extinctions to be $A_V \approx 1.4$ and 4.4, respectively. HH 119 A is found to expand much faster than expected from linear expansion with distance from the outflow source. Using planar shock models we find shock velocities of ~ 60 km s⁻¹ (A) and ~ 35 km s⁻¹ (B and C). This agrees with A being of higher excitation than B and C. In our *U* image we detect three of the HH objects and propose that the emission arise from the [OII] λ 3728 line and the blue continuum. New SPITZER/IRAC and MIPS observations show most of the HH objects at 4.5 μ m and a E–W elongated hour-glass shaped structure at the outflow source. Even at 24 μ m it is not clear whether most of the light is direct or reflected.

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Spatially extended PAHs in circumstellar disks around T Tauri and Herbig Ae stars

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Our aim is to determine the presence and location of the emission from polycyclic aromatic hydrocarbons (PAHs) towards low and intermediate mass young stars with disks using large aperture telescopes.

VLT-VISIR N-band spectra and VLT-ISAAC and VLT-NACO L-band spectra of 29 sources are presented, spectrally resolving the 3.3, 8.6, 11.2, and 12.6 μ m PAH features. Spatial-extent profiles of the features and the continuum emission have been derived and used to associate the PAH emission with the disks. The results are discussed in the

context of recent PAH-emission disk models.

The 3.3, 8.6, and 11.2 μm PAH features are detected toward a small fraction of the T Tauri stars, with typical upper limits between 1×10^{-15} and 5×10^{-17} W m^{-2} . All 11.2 μm detections from a previous Spitzer survey are confirmed with (tentative) 3.3 μm detections, and both the 8.6 and the 11.2 μm features are detected in all PAH sources. For 6 detections, the spatial extent of the PAH features is confined to scales typically smaller than $0.12\text{--}0.34''$, consistent with the radii of 12-60 AU disks at their distances (typically 150 pc). For 3 additional sources, WL 16, HD 100546, and TY CrA, one or more of the PAH features are more extended than the hot dust continuum of the disk, whereas for Oph IRS 48, the size of the resolved PAH emission is confirmed as smaller than for the large grains. For HD 100546, the 3.3 μm emission is confined to a small radial extent of 12 ± 3 AU, most likely associated with the outer rim of the gap in this disk. Gaps with radii out to 10–30 AU may also affect the observed PAH extent for other sources. For both Herbig Ae and T Tauri stars, the small measured extents of the 8.6 and 11.2 μm features are consistent with larger (≥ 100 carbon atoms) PAHs.

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A Search for 6.7 GHz Methanol Masers in M3

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We report the negative results from a search for 6.7 GHz methanol masers in the nearby spiral galaxy M33. We observed 14 GMCs in the central 4 kpc of the Galaxy, and found 3 sigma upper limits to the flux density of ~ 9 mJy in spectral channels having a velocity width of 0.069 km/s. By velocity shifting and combining the spectra from the positions observed, we obtain an effective sigma upper limit on the average emission of ~ 1 mJy in a 0.25 km/s channel. These limits lie significantly below what we would expect based on our estimates of the methanol maser luminosity function in the Milky Way. The most likely explanation for the absence of detectable methanol masers appears to be the metallicity of M33, which is modestly less than that of the Milky Way.

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The X-ray soft excess in classical T Tauri stars

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Aims: We study an anomaly in the X-ray flux (or luminosity) ratio between the O VII $\lambda\lambda 21.6\text{--}22.1$ triplet and the O VIII Ly α line seen in classical T Tauri stars (CTTS). This ratio is unusually high when compared with ratios for main-sequence and non-accreting T Tauri stars (Telleschi et al. 2007). We compare these samples to identify the source of the excess. A sample of recently discovered X-ray stars with a soft component attributed to jet emission is also considered.

Methods: We discuss data obtained from the *XMM-Newton Extended Survey of the Taurus Molecular Cloud* (XEST) project, complemented by data from the published literature. We also present data from the CTTS RU Lup.

Results: All CTTS in the sample show an anomalous O VII/O VIII flux ratio when compared with WTTS or MS stars. The anomaly is due to an *excess* of cool, O VII emitting material rather than a deficiency of hotter plasma. The excess plasma must therefore have temperatures of less than approximately 2 MK. This *soft excess* does not correlate with UV excesses of CTTS, but seems to be related with the stellar X-ray luminosity. The spectra of the jet-driving TTS

do not fit into this picture.

Conclusions: The soft excess depends both on the presence of accretion streams in CTTS and on magnetic activity. The gas may be shock-heated near the surface, although it may also be heated in the magnetospheric accretion funnels. The soft component of the jet-driving sources is unlikely to be due to the same process.

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<http://www.astro.phys.ethz.ch/papers/guedel/papers.html>

***Spitzer* Observations of NGC 1333: A Study of Structure and Evolution in a Nearby Embedded Cluster**

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We present a comprehensive analysis of structure in the young, embedded cluster, NGC 1333 using members identified with *Spitzer* and 2MASS photometry based on their IR-excess emission. In total, 137 members are identified in this way, composed of 39 protostars and 98 more evolved pre-main sequence stars with disks. Of the latter class, four are transition/debris disk candidates. The fraction of exposed pre-main sequence stars with disks is $83\% \pm 11\%$, showing that there is a measurable diskless pre-main sequence population. The sources in each of the Class I and Class II evolutionary states are shown to have very different spatial distributions relative to the distribution of the dense gas in their natal cloud. However, the distribution of nearest neighbor spacings among these two groups of sources are found to be quite similar, with a strong peak at spacings of 0.045 pc. Radial and azimuthal density profiles and surface density maps computed from the identified YSOs show that NGC 1333 is elongated and not strongly centrally concentrated, confirming previous claims in the literature. We interpret these new results as signs of a low velocity dispersion, extremely young cluster that is not in virial equilibrium.

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Orbital Evolution of Planetesimals due to the Galactic Tide: Formation of the Comet Cloud

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We have investigated the orbital evolution of planetesimals perturbed by the Galactic tide using analytical expressions. We consider the vertical component of the tidal force from the Galactic disk. The Galactic tide increases or decreases the perihelia and randomizes the inclination of planetesimals with large aphelion distances. We applied the analytical solutions to the orbital evolution of planetesimals that form the Oort Cloud from the planetesimal disk. Due to the Galactic tide, some planetesimals with small angular momentum show substantial inverse variations of the eccentricity and inclination. Also, some planetesimals show libration of the argument of perihelion ω around $\omega = 90^\circ$ or 270° (the Lidov-Kozai mechanism). The planetesimals that gain perihelion distances great enough to leave the planetary region become members of the Oort Cloud. We find that due to the Galactic tide, planetesimals with semimajor axes $\gtrsim 1000$ AU increase their perihelion distances outside the planetary region ($\gtrsim 100$ AU), and planetesimals with semimajor axes $\gtrsim 20,000$ AU spread their inclinations to the Galactic plane (the Galactic inclinations) over the range 0° - 90° in 5 Gyr. We also consider the effect of a dense Galactic environment on the Oort Cloud formation and discuss the comet clouds for other planetary systems with different Galactic inclinations.

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High-resolution polarimetry of Parsamian 21: revealing the structure of an edge-on FU Ori disc

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We present the first high spatial resolution near-infrared direct and polarimetric observations of Parsamian 21, obtained with the VLT/NACO instrument. We complemented these measurements with archival infrared observations, such as HST/WFPC2 imaging, HST/NICMOS polarimetry, Spitzer IRAC and MIPS photometry, Spitzer IRS spectroscopy as well as ISO photometry. Our main conclusions are the following: (1) we argue that Parsamian 21 is probably an FU Orionis-type object; (2) Parsamian 21 is not associated with any rich cluster of young stars; (3) our measurements reveal a circumstellar envelope, a polar cavity and an edge-on disc; the disc seems to be geometrically flat and extends from approximately 48 to 360 AU from the star; (4) the SED can be reproduced with a simple model of a circumstellar disc and an envelope; (5) within the framework of an evolutionary sequence of FUors proposed by Green et al. (2006) and Quanz et al. (2007), Parsamian 21 can be classified as an intermediate-aged object.

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The Statistics of Supersonic Isothermal Turbulence

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We present results of large-scale three-dimensional simulations of supersonic Euler turbulence with the piecewise parabolic method and multiple grid resolutions up to 2048³ points. Our numerical experiments describe non-magnetized driven turbulent flows with an isothermal equation of state and an rms Mach number of 6. We discuss numerical resolution issues and demonstrate convergence, in a statistical sense, of the inertial range dynamics in simulations on grids larger than 512³ points. The simulations allowed us to measure the absolute velocity scaling exponents for the first time. The inertial range velocity scaling in this strongly compressible regime deviates substantially from the incompressible Kolmogorov laws. The slope of the velocity power spectrum, for instance, is -1.95 compared to $-5/3$ in the incompressible case. The exponent of the third-order velocity structure function is 1.28, while in incompressible turbulence it is known to be unity. We propose a natural extension of Kolmogorov's phenomenology that takes into account compressibility by mixing the velocity and density statistics and preserves the Kolmogorov scaling of the power spectrum and structure functions of the density-weighted velocity $pmbv \equiv \rho^{1/3}pmbu$. The low-order statistics of $pmbv$ appear to be invariant with respect to changes in the Mach number. For instance, at Mach 6 the slope of the power spectrum of $pmbv$ is -1.69 , and the exponent of the third-order structure function of $pmbv$ is unity. We also directly measure the mass dimension of the "fractal" density distribution in the inertial subrange, $D_m \approx 2.4$, which is similar to the observed fractal dimension of molecular clouds and agrees well with the cascade phenomenology.

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Three-Dimensional Observations of H₂ Emission around Sgr A East - I. Structure in the Central 10 Parsecs of Our Galaxy

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We have obtained velocity-resolved spectra of the H₂v = 1 – 0S(1)($\lambda = 2.1218\mu\text{m}$) emission line at 2 arcsec angular resolution (or ~ 0.08 pc spatial resolution) in four regions within the central 10 pc of the Galaxy where the supernova-like remnant Sgr A East is colliding with molecular clouds. To investigate the kinematic, physical, and positional relationships between the important gaseous components in the center, we compared the H₂ data cube with previously published NH₃ data. The projected interaction-boundary of Sgr A East is determined to be an ellipse with its center offset ~ 1.5 pc from Sgr A* and dimensions of 10.8 pc \times 7.6 pc. This H₂ boundary is larger than the synchrotron emission shell but consistent with the dust ring which is believed to trace the shock front of Sgr A East. Since Sgr A East is driving shocks into its nearby molecular clouds, we can determine their positional relationships using the shock directions as indicators. As a result, we suggest a revised model for the three-dimensional structure of the central 10 pc. The actual contact between Sgr A East and all of the surrounding molecular material, including the circum-nuclear disk and the southern streamer, makes the hypothesis of infall into the nucleus and feeding of Sgr A* very likely.

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Magnetic Intensification of the Li I $\lambda 6708$ Line and the Abundance and Age Spread in Young Cool Stars

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The lithium abundance is considered the best age indicator of young cool stars and its spread is fundamental for the understanding of star formation mechanisms, in particular, of possible multiple formation events within a single region. The observed spread in the equivalent widths of lithium lines cannot be understood on the basis of present stellar evolutionary models, and proposed explanations invoke stellar activity. Despite the fact that magnetic fields of several tenths of a tesla are expected theoretically and are observed in these stars, their effect on the formation of spectral lines has always been neglected. In this Letter, the possibility that the magnetic intensification of spectral lines results in an overestimation of lithium abundances is quantitatively explored through the computation of Stokes I profiles of the Li I $\lambda 6708$ doublet, using the polarized line synthesis code COSSAM. Spectral synthesis for fields up to 1 T reveals the doublet to be sensitive to magnetic fields, with equivalent widths up to 60% larger than the zero field value and a possible overestimation of lithium abundances by 1 dex. Consequently, the contribution of magnetic fields to the lithium spread appears to be significant. Neglecting the magnetic intensification of the Li I $\lambda 6708$ doublet could make stars appear millions of years younger and make stellar formation mechanisms appear to last much longer than usually supposed. To conclude, for lithium abundance determinations and estimates of lithium based stellar ages, one has to obtain magnetic field measurements and to include them in the spectrum analysis.

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A Flattened Protostellar Envelope in Absorption around L1157

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Deep *Spitzer* IRAC images of L1157 reveal many of the details of the outflow and the circumstellar environment of this Class 0 protostar. In IRAC band 4, 8 μm , there is a flattened structure seen in absorption against the background emission. The structure is perpendicular to the outflow and is extended to a diameter of $\sim 2'$. This structure is the first clear detection of a flattened circumstellar envelope or pseudo-disk around a Class 0 protostar. Such a flattened morphology is an expected outcome for many collapse theories that include magnetic fields or rotation. We construct an extinction model for a power-law density profile, but we do not constrain the density power-law index.

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Search for HH Objects and Emission Stars in Star Formation Regions. IV. New HH flows and HH objects related with cometary nebulae.

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The results of the observations in the environments of the five cometary nebulae: MacC H12, MacC sH15, GM 1-14, RNO 33, Pars 17, are presented. This search was performed in the frames of the continuing survey of new HH objects in star formation regions. Nine previously unknown HH-objects were found. Nearly all these objects belong to directed outflows, the sources of which are with high probability the central stars of the listed above nebulae. In the cases of MacC H12 and GM 1-14 the outflows have distinct bipolar structure. The position of the sources on J-H/H-K diagram is discussed.

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Search for HH Objects and Emission Stars in Star Formation Regions. V. Two new cometary nebulae in Perseus cloud.

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A small area of the Perseus dark cloud around LkH α 326 emission line star is studied in the optical range. Two new cometary nebulae are described, and their connection with previously found HH objects is discussed. A small HH-jet is discovered near the central star of one of these nebulae. Six emission-line stars, including four new ones, are found in this area by means of slitless spectroscopy.

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Using Chemistry to Unveil the Kinematics of Starless Cores: Complex Radial Motions in Barnard 68

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We present observations of ^{13}CO , C^{18}O , HCO^+ , H^{13}CO^+ , DCO^+ and N_2H^+ line emission towards the Barnard 68 starless core. The line profiles are interpreted using a chemical network coupled with a radiative transfer code in order to reconstruct the radial velocity profile of the core. Our observations and modeling indicate the presence of complex radial motions, with the inward motions in the outer layers of the core but outward motions in the inner part, suggesting radial oscillations. The presence of such oscillation would imply that B68 is relatively old, typically one order of magnitude older than the age inferred from its chemical evolution and statistical core lifetimes. Our study demonstrates that chemistry can be used as a tool to constrain the radial velocity profiles of starless cores.

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Massive star-formation in G24.78+0.08 explored through VLBI maser observations

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Previous interferometric observations have demonstrated that, across a distance of a few 0.1 pc, the high-mass star forming region (SFR) G24.78+0.08 contains at least four distinct centers of massive star formation, possibly in different evolutionary stages. This study aims to provide a detailed picture of the physical environment and the gas kinematics in a cluster of high-mass YSOs. Using EVN (single epoch) and VLBA (four epochs) phase-referenced observations, we have derived the absolute positions and velocities for 6.7 GHz methanol and 22.2 GHz water masers, respectively. Using the BIMA and VLA interferometers, positions and line of sight velocities of 95 GHz and 44 GHz methanol masers, are also obtained. The derived interferometric and VLBI maser maps are compared with previous sub-arcsecond maps of the G24.78+0.08 region, observed in thermal continuum and molecular line tracers. In the hot molecular cores G24 A1 and G24 A2, 6.7 GHz methanol and 22.2 GHz water masers are emerging at similar positions and line of sight velocities, which suggests that in both cores a same YSO is responsible for the excitation of the two types of maser emission. At the center of the G24 A1 core, water masers distribute along an arc at the border of a hyper-compact HII region (of size ≈ 1000 AU) and expand away from the center of the HII region with high velocities (≈ 40 km s⁻¹). We think that such a fast expansion is driven by a strong stellar wind emitted by the star exciting the hyper-compact HII region. This outflowing motion might dominate the gas kinematics of G24 A1 also at larger (≈ 0.1 pc) scale, where a well defined velocity gradient in the CH₃CN line and 6.7 GHz masers is observed. Alternatively, water masers might mark the border of the dynamical interaction between the evolving star and harboring core, and the gas surrounding the hyper-compact HII region, not yet affected by the expansion of the ionized gas, might be still rotating and, perhaps, slightly contracting. In the G24 C core, water maser spots show very fast (100–200 km s⁻¹) and nearly parallel proper motions, which might indicate that the water maser emission is tracing a collimated jet.

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Crystallization Experiments on Amorphous Silicates with Chondritic Composition: Quantitative Formulation of the Crystallization

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In order to make clear crystallization process of silicates in circumstellar environments of oxygen-rich young stars, we

have performed laboratory experiments on crystallization of a silicate material by use of a synthetic sample with the chondritic composition for the first time. The aim of this work is to analyze the crystallization process quantitatively using the amorphous material with the chondritic composition. The starting amorphous material was synthesized by the sol-gel method. The sample was heated at 660°-1200°C for 0.5-12 hr to investigate the temperature and time dependence of the crystallization. The run products were analyzed using infrared absorption spectroscopy, X-ray diffraction, scanning electron microscopy and transmission electron microscopy. Olivine [(Mg, Fe)₂SiO₄] was mainly crystallized from the starting amorphous material. We performed infrared spectral fittings of the heated samples using individual spectra of olivine and amorphous silicate, and estimated the degree of crystallization quantitatively. The time-dependent crystallization process could be formulated using the Johnson-Mehl-Avrami equation with the power of about 1.2, which is consistent with theoretical crystallization model of three-dimensional diffusion-controlled growth from a state that a number of nuclei is constant. The constant number of nuclei corresponds to the starting material, which contains crystallites of magnetite (Fe₃O₄) and ferrihydrite (5Fe₂O₃·9H₂O) as nucleation sites of olivine crystals. From the quantitative analyses, we suggest that crystallization processes in circumstellar regions should depend on properties of the interstellar amorphous silicates such as existence of crystallites and/or FeO content.

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Medium-separation binaries do not affect the first steps of planet formation

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The first steps of planet formation are marked by the growth and crystallization of sub-micrometer-sized dust grains accompanied by dust settling toward the disk midplane. In this paper we explore whether the first steps of planet formation are affected by the presence of medium-separation stellar companions. We selected two large samples of disks around single and binary T Tauri stars in Taurus that are thought to have only a modest age spread of a few Myr. The companions of our binary sample are at projected separations between ~10 and 450 AU with masses down to about 0.1 solar mass. We used the strength and shape of the 10 micron silicate emission feature as a proxy for grain growth and for crystallization respectively. The degree of dust settling was evaluated from the ratio of fluxes at two different mid-infrared wavelengths. We find no statistically significant difference between the distribution of 10 micron silicate emission features from single and binary systems. In addition, the distribution of disk flaring is indistinguishable between the single and binary system samples. These results show that the first steps of planet formation are not affected by the presence of a companion at tens of AU.

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Quasi-binarity of massive stars in young dense clusters - the case of the ONC

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Context. Observations indicate that in young stellar clusters the binary fraction for massive stars is higher than for solar mass stars. For the Orion Nebula Cluster (ONC) there is a binary frequency of ~ 50% for solar-mass stars compared to 70-100% for the massive O- and B-stars.

Aims. We explore the reasons for this discrepancy and come up with two possible answers: a) a primordially higher binarity of massive stars could be inherent to the star formation process or b) the primordial binary rate might be the same for solar-mass and massive stars, but the higher capture cross section of the massive stars possibly leads to the formation of additional massive binaries in the early cluster development. Here we investigate the likelihood of the latter scenario in detail using the ONC as an example.

Method. N-body simulations are performed to track the capture events in an ONC-like cluster.

Results. We find that whereas low-mass stars rarely form bound systems through capture, the dynamics of the massive stars - especially in the first 0.5 Myrs - is dominated by a rapid succession of “transient binary or multiple systems”. In observations the transient nature of these systems would not be apparent, so that they would be rated as binaries. At 1-2 Myrs, the supposed age of the ONC, the “transient” massive systems become increasingly stable, lasting on average several 10^6 yrs. Despite the ONC being so young, the observed binary frequency for massive stars — unlike that of solar-mass stars — is not identical to the primordial binary frequency but is increased by at least 10-15% through dynamical interaction processes. This value might be increased to at least 20-25% by taking disc effects into account.

Conclusions. The primordial binary frequency could well be the same for massive and solar mass stars because the observed difference can be explained by capture processes alone.

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Modeling the water line emission from the high-mass star-forming region AFGL 2591

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Context: Observations of water lines are a sensitive probe of the geometry, dynamics and chemical structure of dense molecular gas. The launch of Herschel with on board HIFI and PACS allow to probe the behaviour of multiple water lines with unprecedented sensitivity and resolution.

Aims: We investigate the diagnostic value of specific water transitions in high-mass star-forming regions. As a test case, we apply our models to the AFGL 2591 region.

Methods: A multi-zone escape probability method is used in two dimensions to calculate the radiative transfer. Similarities and differences of constant and jump abundance models are displayed, as well as when an outflow is incorporated.

Results: In general, for models with a constant water abundance, the ground state lines, i.e., $1_{10}-1_{01}$, $1_{11}-0_{00}$, and $2_{12}-1_{01}$, are predicted in absorption, all the others in emission. This behaviour changes for models with a water abundance jump profile in that the line profiles for jumps by a factor of $\sim 10-100$ are similar to the line shapes in the constant abundance models, whereas larger jumps lead to emission profiles. Asymmetric line profiles are found for models with a cavity outflow and depend on the inclination angle. Models with an outflow cavity are favoured to reproduce the SWAS observations of the $1_{10}-1_{01}$ ground-state transition. PACS spectra will tell us about the geometry of these regions, both through the continuum and through the lines.

Conclusions: It is found that the low-lying transitions of water are sensitive to outflow features, and represent the excitation conditions in the outer regions. High-lying transitions are more sensitive to the adopted density and temperature distribution which probe the inner excitation conditions. The Herschel mission will thus be very helpful to constrain the physical and chemical structure of high-mass star-forming regions such as AFGL 2591.

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Planetary embryos and planetesimals residing in thin debris discs

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We consider constraints on the planetesimal population residing in the discs of AU Microscopii (AU Mic), β Pictoris (β Pic) and Fomalhaut taking into account their observed thicknesses and normal disc opacities. We estimate that bodies of radius 5, 180 and 70 km are responsible for initiating the collisional cascade accounting for the dust production for AU Mic, β Pic and Fomalhaut’s discs, respectively, at break radii from the star where their surface brightness profiles change slope. Larger bodies, of radius 1000 km and with surface density of the order of 0.01 g cm^{-2} , are required to

explain the thickness of these discs assuming that they are heated by gravitational stirring. A comparison between the densities of the two sizes suggests the size distribution in the largest bodies is flatter than that observed in the Kuiper belt. AU Mic’s disc requires the shallowest size distribution for bodies with radius greater than 10 km suggesting that the disc contains planetary embryos experiencing a stage of runaway growth.

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The Three-dimensional Structure of a Radiative, Cosmic Bullet Flow

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We have carried out an axisymmetric and a three-dimensional (3D) numerical simulation of a radiative, interstellar bullet flow with the same physical and numerical setup. We find that while some of the main features of the axisymmetric flow are reproduced in the 3D simulation (e.g., the production of “vortex shedding events” and the fragmentation of the head of the bullet flow), strong deviations from axisymmetry occur in the 3D flow. The main difference between the axisymmetric and the 3D flows is that the on-axis, high-velocity condensation that is characteristic of the axisymmetric flow does not appear in the 3D bullet flow.

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A Parallax Distance of 389_{-21}^{+24} Parsecs to the Orion Nebula Cluster from Very Long Baseline Array Observations

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We determine the parallax and proper motion of the flaring, nonthermal radio star GMR A, a member of the Orion Nebula Cluster, using Very Long Baseline Array observations. Based on the parallax, we measure a distance of 389_{-21}^{+24} pc to the source. Our measurement places the Orion Nebula Cluster considerably closer than the canonical distance of 480 ± 80 pc determined by Genzel et al. A change of this magnitude in distance lowers the luminosities of the stars in the cluster by a factor of ~ 1.5 . We briefly discuss two effects of this change: an increase in the age spread of the pre-main-sequence stars, and better agreement between the zero-age main sequence and the temperatures and luminosities of massive stars.

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The Rapid Outbursting Star GM Cep: An EX-or in Tr 37?

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We present optical, IR and millimeter observations of the solar-type star 13-277, also known as GM Cep, in the 4

Myr-old cluster Tr 37. GM Cep experiences rapid magnitude variations of more than 2 mag at optical wavelengths. We explore the causes of the variability, which seem to be dominated by strong increases in the accretion, being similar to EX-or episodes. The star shows high, variable accretion rates (up to $\sim 10^{-6} M_{\odot}/\text{yr}$), signs of powerful winds, and it is a very fast rotator ($V\text{ sini} \sim 43$ km/s). Its strong mid-IR excesses reveal a very flared disk and/or a remnant envelope, most likely out of hydrostatic equilibrium. The 1.3 millimeter fluxes suggest a relatively massive disk ($M_D \sim 0.1 M_{\odot}$). Nevertheless, the millimeter mass is not enough to sustain increased accretion episodes over large timescales, unless the mass is underestimated due to significant grain growth. We finally explore the possibility of GM Cep having a binary companion, which could trigger disk instabilities producing the enhanced accretion episodes.

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X-ray detection of the substellar twin 2MASS J11011926-7732383 AB

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Context. 2MASS J11011926-7732383 AB (hereafter 2M 1101 AB), located in the Cha I star forming region, is a rare wide-separation brown dwarf binary. Being spatially resolvable in many wavebands, it is a unique target for studying the properties of substellar twins.

Aims. Here, we exploit the coeval pair 2M 1101 AB to examine the influence of physical parameters (mass, bolometric luminosity and effective temperature) on X-ray emission from substellar objects.

Methods. We determine the X-ray properties of 2M 1101 A and B using XMM-Newton and Chandra observations.

Results. The spatial resolution of XMM-Newton is not sufficient to separate contributions from the two components in the binary. The X-ray source detected with XMM-Newton has a column density compatible with the infrared extinction of component A. On the other hand, the binary is resolved with Chandra, and the bulk of the X-ray emission is clearly associated with the photospherically cooler component B. These apparently contradictory results point at strong variability of 2 M1101's X-ray emission. Combined with previous sensitive X-ray observations from low-mass members of Cha I, we find a decline of X-ray luminosity with decreasing (sub)stellar mass that is typical for star forming regions.

Conclusions. 2M 1101 B is the coolest (spectral type M8.25) and least massive brown dwarf of Cha I detected in X-rays so far. It is also among the youngest (~ 1 Myr) substellar Cha I members, and therefore relatively luminous. Most bona fide brown dwarfs of Cha I have remained below the sensitivity limits of available X-ray observations, because of their low luminosity associated with higher age.

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The Outflow from the Luminous Young Stellar Object IRAS 20126+4104: from 4000 AU to 0.4 pc

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We have imaged the outflow from the luminous young stellar object IRAS 20126+4104 (I20126) with the Submillimeter Array in CO (3–2), HCN (4–3), and SiO (5–4) at $1''$ – $2''$ resolutions within a radius of $\sim 20''$ from the central driving source. Our observations reveal at least three different components of the outflowing gas: (i) a compact (~ 4000 AU) bipolar outflow toward the central young stellar object. With a dynamical timescale of ~ 120 years, this component represents a very new jet/outflow activity in I20126. (ii) a collimated outflow with an extent of ~ 0.2 pc previously detected in SiO (2–1). Both morphology and kinematics favor this component being a jet-driven bow shock system.

(iii) an S-shaped CO outflow with an extent of ~ 0.4 pc. This component records the precession history very well. Its kinematic feature, where the velocity increasing with distance from the YSO, indicates, independently to other evidences, that the outflow axis is moving towards the plane of the sky. The three outflow components record the history of the primary jet precession over scales ranging from a few hundreds AU to approximately 0.4 pc. Our results indicate that CO (3–2) emission is a good tracer to probe the primary jet. The gas densities and SiO relative abundances in I20126 shocks are estimated using the large velocity gradient calculations. The inferred SiO abundances of $(1-5)\times 10^{-8}$ in I20126 outflow lobes are comparable to the expected enhancement at shocked regions.

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Micro Molecular Bipolar Outflow From HL Tau

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We present detailed geometry and kinematics of the inner outflow toward HL Tau observed using Near Infrared Integral Field Spectrograph (NIFS) at the Gemini-North 8-m Observatory. We analyzed H₂ 2.122 μ m emission and [Fe II] 1.644 μ m line emission as well as the adjacent continuum observed at a $<0''.2$ resolution. The H₂ emission shows (1) a bubble-like geometry to the northeast of the star, as briefly reported in the previous paper, and (2) faint emission in the southwest counterflow, which has been revealed through careful analysis. The emission on both sides of the star show an arc $1''.0$ away from the star, exhibiting a bipolar symmetry. Different brightness and morphologies in the northeast and southwest flows are attributed to absorption and obscuration of the latter by a flattened envelope and a circumstellar disk. The H₂ emission shows a remarkably different morphology from the collimated jet seen in [Fe II] emission. The positions of some features coincide with scattering continuum, indicating that these are associated with cavities in the dusty envelope. Such properties are similar to millimeter CO outflows, although the spatial scale of the H₂ outflow in our image (~ 150 AU) is strikingly smaller than the mm outflows, which often extend over 1000–10000 AU scales. The position-velocity diagram of the H₂ and [Fe II] emission do not show any evidence for kinematic interaction between these flows. All results described above support the scenario that the jet is surrounded by an unseen wide-angled wind, which interacts with the ambient gas and produce the bipolar cavity and shocked H₂ emission.

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Highly Collimated Jets and Wide-Angle Outflows in HH 46/47: New Evidence from Spitzer Infrared Images

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We present new details of the structure and morphology of the jets and outflows in HH 46/47 as seen in Spitzer infrared images from IRAC and MIPS, reprocessed using the “HiRes” deconvolution technique. HiRes improves the visualization of spatial morphology by enhancing resolution (to subarcsecond levels in IRAC bands) and removing the contaminating side lobes from bright sources. In addition to sharper views of previously reported bow shocks, we have detected (1) the sharply delineated cavity walls of the wide-angle biconical outflow, seen in scattered light on both sides of the protostar, (2) several very narrow jet features at distances ~ 400 AU to ~ 0.1 pc from the star, and

(3) compact emissions at MIPS 24 μm coincident with the jet heads, tracing the hottest atomic/ionic gas in the bow shocks. Together the IRAC and MIPS images provide a more complete picture of the bow shocks, tracing both the molecular and atomic/ionic gases, respectively. The narrow width and alignment of all jet-related features indicate a high degree of jet collimation and low divergence (width of ~ 400 AU increasing by only a factor of 2.3 over 0.2 pc). The morphology of this jet, bow shocks, wide-angle outflows, and the fact that the jet is nonprecessing and episodic, constrain the mechanisms for producing the jet's entrained molecular gas, and origins of the fast jet, and slower wide-angle outflow.

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The CO Molecular Outflows of IRAS 16293-2422 Probed by the Submillimeter Array

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We have mapped the proto-binary source IRAS 16293–2422 in CO 2–1, ¹³CO 2–1, and CO 3–2 with the Submillimeter Array (SMA). The maps with resolution of 1.5–5'' reveal a single small scale (~ 3000 AU) bipolar molecular outflow along the east-west direction. We found that the blueshifted emission of this small scale outflow mainly extends to the east and the redshifted emission to the west from the position of IRAS 16293A. A comparison with the morphology of the large scale outflows previously observed by single-dish telescopes at millimeter wavelengths suggests that the small scale outflow may be the inner part of the large scale (~ 15000 AU) E–W outflow. On the other hand, there is no clear counterpart of the large scale NE–SW outflow in our SMA maps. Comparing analytical models to the data suggests that the morphology and kinematics of the small scale outflow can be explained by a wide-angle wind with an inclination angle of $\sim 30^\circ$ – 40° with respect to the plane of the sky. The high resolution CO maps show that there are two compact, bright spots in the blueshifted velocity range. An LVG analysis shows that the one located 1'' to the east of source A is extremely dense, $n(\text{H}_2) \sim 10^7 \text{ cm}^{-3}$, and warm, $T_{\text{kin}} > 55$ K. The other one located 1'' southeast of source B has a higher temperature of $T_{\text{kin}} > 65$ K but slightly lower density of $n(\text{H}_2) \sim 10^6 \text{ cm}^{-3}$. It is likely that these bright spots are associated with the hot core-like emission observed toward IRAS 16293. Since both two bright spots are blueshifted from the systemic velocity and are offset from the protostellar positions, they are likely formed by shocks.

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Formation of Massive Primordial Stars in a Reionized Gas

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We use cosmological hydrodynamic simulations with unprecedented resolution to study the formation of primordial stars in an ionized gas at high redshifts. Our approach includes all the relevant atomic and molecular physics to follow the thermal evolution of a prestellar gas cloud to very high densities of $\sim 10^{18} \text{ cm}^{-3}$. We locate a star-forming gas cloud within a reionized region in our cosmological simulation. The gas cloud cools down to a few tens of kelvins by HD line cooling, and this is lower than possible by H₂ cooling only. Owing to the low temperature, the first runaway collapse is triggered when the gas cloud's mass is $\sim 40 M_\odot$. We show that the cloud core remains stable against chemothermal instability and also against gravitational deformation throughout its evolution. Consequently, a single

protostellar seed is formed, which accretes the surrounding hot gas at the rate $\dot{M} \gtrsim 10^{-3} M_{\odot} \text{ yr}^{-1}$. We carry out protostellar evolution calculations using the inferred accretion rate. The resulting mass of the star when it reaches the zero-age main sequence is $M_{ZAMS} \sim 40 M_{\odot}$. Since the obtained M_{ZAMS} is as large as the mass of the collapsing parent cloud, the final stellar mass is likely close to this value. Such massive, rather than exceptionally massive, primordial stars are expected to cause early chemical enrichment of the universe by exploding as black holeforming super/hypernovae and may also be progenitors of high-redshift γ -ray bursts. The elemental abundance patterns of recently discovered hypermetal-poor stars suggest that they might have been born from the interstellar medium that was metal-enriched by the supernovae of these massive primordial stars.

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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), *Abstracts of recently accepted major reviews* (not standard conference contributions), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star and planet formation and early solar system community), *New Jobs* (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and *Short Announcements* (where you can inform or request information from the community).

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each issue of the newsletter. You can also submit via the Newsletter web interface at <http://www2.ifa.hawaii.edu/star-formation/index.cfm>

The Star Formation Newsletter is available on the World Wide Web at <http://www.ifa.hawaii.edu/users/reipurth> or at <http://www.eso.org/gen-fac/pubs/starform/>.

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.

Postdoctoral research position in star formation

Applications are invited for a postdoctoral research position at the University of Geneva (Geneva Observatory and the affiliated ISDC) in Switzerland to start as soon as possible.

The successful candidate will be member of the research group led by Prof. Marc Audard in the field of star formation (<http://isdc.unige.ch/youngstars>). The group's research interests focus on the study of star formation through multi-wavelength observations (from X-rays to radio).

Candidates with experience in (sub-)millimeter observations of star forming regions, jets and molecular outflows, and disks are particularly encouraged to apply. Applications from candidates with theoretical expertise in the interpretation of (sub-)millimeter data are also welcome. The successful candidate is expected to collaborate with the group and will also be encouraged to pursue independent research.

The appointment is for one year and may be extended to a second year, should additional funds become available. Salary ranges from about 64,000 to 73,000 Swiss Francs, depending on experience. Funds for research expenses and travel are available as well.

Candidates should send a curriculum vitae, a publication list, a description of research interests and plans. They should also arrange for two letters of recommendation to be sent by e-mail (preferred) or directly to the address below. Applications will be accepted until the position is filled.

Contact and submission address: Prof. Marc Audard (Marc.Audard *at* obs.unige.ch), ISDC and Geneva Observatory, Ch. d'Ecogia 16, 1290 Versoix, Switzerland.

Postdoctoral Position in Star Formation Research

The Department of Physics and Astronomy at Rice University is accepting applications for a postdoctoral position in observational astronomy. The position is available immediately and will remain open until filled. The applicant will work with Dr. Patrick Hartigan on topics related to stellar jets, shock waves, and star formation. The position is for two years and offers a salary of \$40,000 each year, with a possibility of being augmented to \$60,000 per year through the G.K. Walters postdoctoral fellowship (see <http://www.physics.rice.edu> for more details about the Walters fellowship and the Department). Rice University is a beautiful, small, Research-I University located in the fourth largest city in the US. Applicants should submit their curriculum vitae, a one-page summary of research interests, and arrange for three letters of recommendation to be sent to the following address: Dr. Patrick Hartigan, Department of Physics and Astronomy, Mail Stop 108, Rice University, 6100 S. Main, Houston TX 77005.

PLANETARY SCIENCE - tenure stream positions at University of Toronto, Scarborough

PLANETARY SCIENCE - TENURE STREAM POSITIONS

The Department of Physical and Environmental Sciences (DPES) at the University of Toronto Scarborough (UTSC) invites applications for two tenure track positions in the field of planetary physics. We seek outstanding applicants from a broad range of disciplines related to the study of solar system objects and planets. The positions will enhance an initiative within the department's Planetary Physics group to expand its research activity in fields related to the structure, dynamics, origin and evolution of planets and planetary systems. Our department is home to chemical, environmental and planetary sciences researchers (cf. <http://www.utsc.utoronto.ca/~physsci/>). The applications should reflect how candidates would integrate in this environment. We encourage applications from candidates with theoretical, computational, experimental or combined research interests. High performance computing is supported within the Department through access to the UTSC and other computing grids. The positions are expected to be filled at the level of Assistant Professor. The successful candidates will hold a graduate appointment in the Department of Physics or Astronomy and Astrophysics of U of T. Excellent opportunities for collaboration with these departments and CITA exist. Salary will be commensurate with qualifications and experience. A negotiable starting date is July 1, 2008.

Applications will be accepted until January 15, 2008. For the full description of the position and application (required documents) please see the DPES page <http://www.utsc.utoronto.ca/~physsci/jobs/faculty.shtml> . Informal inquiries are welcome by Prof. P. Artymowicz at pawel@utsc.utoronto.ca.

Meetings

The Cosmic Agitator - Magnetic Fields in the Galaxy

60 years of studies of the interstellar magnetic field

2008 March 26-29 Lexington KY, USA

The magnetic field of the galaxy was discovered in observations made in 1948. Since that time, the galactic magnetic field has challenged (and often annoyed) observers and theorists alike. This meeting will celebrate sixty years of studies of the interstellar magnetic field.

The meeting will take place in Lexington, Kentucky USA, in the heart of the beautiful Bluegrass region. Lexington and its environs are known for picturesque countryside, thoroughbred race horses, and fine bourbon whiskey asleep many years in the wood.

The meeting web site is <http://thunder.pa.uky.edu/magnetic> — a tentative schedule is available at this web site, including an updated list of speakers. The registration deadline is 2008 Feb 25, and meeting dates are 2008 Mar 26-29. Interested participants are urged to register early at the web site mentioned above, in order to ensure availability of their preferred slots for contributed talks/posters.

Oral presentations - Oral presentations will occur in the auditorium of the William T. Young Library on the University of Kentucky campus. There will be review talks, approximately 30 minutes long with a 10 minute discussion. There will also be contributed talks, approximately 15 minutes long with a 5 minute discussion.

Poster presentations - The poster session will run concurrently with the oral presentations throughout the conference. The poster session will occur in a gallery adjacent to the conference auditorium. Half hour poster and coffee break periods are scheduled in the middle of each oral session. Coffee and snacks will be served in the poster session gallery, ensuring that posters receive ample attention throughout the conference.

IAU S243 "Star-Disk Interaction in Young Stars" On-Line Proceedings available

The on-line proceedings of the IAU Symposium 243 "Star-Disk Interaction in Young Stars" are now available on the conference website <http://www.iaus243.org>

J. Bouvier & I. Appenzeller, eds