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Abstracts of recently accepted papers

Search for anions in molecular sources: C4H- detection in L1527

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Aims. We present the results of a search for the negative ion C_4H^- in various dark clouds, low mass star-forming regions and photon-dominated regions (PDRs). We have also searched for C_6H^-, C_2H^- and CN^- in some of the sources.
Methods. The millimeter-wave observations were carried out with the IRAM-30 m telescope.
Results. We detect C_4H^-, through the J = 9-8 and J = 10-9 rotational transitions, in the low mass star-forming region L1527. We thus confirm the tentative detection of the J = 9-8 line recently reported toward this source. The $[C_4H^-]$ $/[C_4H]$ ratio found is 0.011%, which is slightly lower than the value observed in IRC +10216, 0.024%, but above the 3σ upper limit we derive in TMC-1, <0.0052%. We have also derived an upper limit for the $[C_6H^-]$ $/[C_6H]$ ratio in the Horsehead Nebula, and for various anion-to-neutral ratios in the observed sources. These results are compared with recent chemical models.

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XMM-Newton X-ray study of early type stars in the Carina OB1 association

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Aims. X-ray properties of the stellar population in the Carina OB1 association are examined with special emphasis on early-type stars. Their spectral characteristics provide some clues to understanding the nature of X-ray formation mechanisms in the winds of single and binary early-type stars.
Methods. A timing and spectral analysis of five observations with XMM-Newton is performed using various statistical tests and thermal spectral models.
Results. 235 point sources have been detected within the field of view. Several of these sources are probably pre-main sequence stars with characteristic short-term variability. Seven sources are possible background AGNs. Spectral

analysis of twenty four sources of type OB and WR 25 was performed. We derived spectral parameters of the sources and their fluxes in three energy bands. Estimating the interstellar absorption for every source and the distance to the nebula, we derived X-ray luminosities of these stars and compared them to their bolometric luminosities. We discuss possible reasons for the fact that, on average, the observed X-ray properties of binary and single early type stars are not very different, and give several possible explanations.

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Molecular tracers of high mass-star formation in external galaxies

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Hot core molecules should be detectable in external active galaxies out to high redshift. We present here a detailed study of the chemistry of star-forming regions under physical conditions that differ significantly from those likely to be appropriate in the Milky Way Galaxy. We examine, in particular, the trends in molecular abundances as a function of time with respect to changes in the relevant physical parameters. These parameters include metallicity, dust:gas mass ratio, the H_2 formation rate, relative initial elemental abundances, the cosmic ray ionization rate, and the temperature of hot cores. These trends indicate how different tracers provide information on the physical conditions and on evolutionary age. We identify hot core tracers for several observed galaxies that are considered to represent spirals, active galaxies, low-metallicity galaxies, and high-redshift galaxies. Even in low-metallicity examples, many potential molecular tracers should be present at levels high enough to allow unresolved detection of active galaxies at high redshift containing large numbers of hot cores. Accepted by ApJ

Discovery of a Wide Companion near the Deuteriumburning Mass Limit in the Upper Scorpius Association

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We present the discovery of a companion near the deuteriumburning mass limit located at a very wide distance, at an angular separation of $4.6'' \pm 0.1''$ (projected distance of $\sim$ 670 AU) from UScoCTIO 108, a brown dwarf of the very young Upper Scorpius association. Optical and nearinfrared photometry and spectroscopy confirm the cool nature of both objects, with spectral types of M7 and M9.5, respectively, and that they are bona fide members of the association, showing low gravity and features of youth. Their masses, estimated from the comparison of their bolometric luminosities and theoretical models for the age range of the association, are 60 ± 20 and 14^{+2}_{-8}, respectively. The existence of this object around a brown dwarf at this wide orbit suggests that the companion is unlikely to have formed in a disk based on current planet formation models. Because this system is rather weakly bound, they probably did not form through dynamical ejection of stellar embryos.

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Detection of amino acetonitrile in Sgr B2(N)

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Context. Amino acids are building blocks of proteins and therefore key ingredients for the origin of life. The simplest amino acid, glycine (NH_2CH_2COOH), has long been searched for in the interstellar medium but has not been unambiguously detected so far. At the same time, more and more complex molecules have been newly found toward the prolific Galactic center source Sagittarius B2.
Aims. Since the search for glycine has turned out to be extremely difficult, we aimed at detecting a chemically related species (possibly a direct precursor), amino acetonitrile (NH_2CH_2CN).
Methods. With the IRAM 30m telescope we carried out a complete line survey of the hot core regions Sgr B2(N) and (M) in the 3 mm range, plus partial surveys at 2 and 1.3 mm. We analyzed our 30m line survey in the LTE approximation and modeled the emission of all known molecules simultaneously. We identified spectral features at the frequencies predicted for amino acetonitrile lines having intensities compatible with a unique rotation temperature. We also used the Very Large Array to look for cold, extended emission from amino acetonitrile.
Results. We detected amino acetonitrile in Sgr B2(N) in our 30m telescope line survey and conducted confirmatory observations of selected lines with the IRAM Plateau de Bure and the Australia Telescope Compact Array interferometers. The emission arises from a known hot core, the Large Molecule Heimat, and is compact with a source diameter of 2 arcsec (0.08 pc). We derived a column density of 2.8×10^{16} cm^{-2}, a temperature of 100 K, and a linewidth of 7 km s^{-1}. Based on the simultaneously observed continuum emission, we calculated a density of 1.7×10^8 cm^{-3}, a mass of 2340 $M_\odot$, and an amino acetonitrile fractional abundance of 2.2×10^{-9}. The high abundance and temperature may indicate that amino acetonitrile is formed by grain surface chemistry. We did not detect any hot, compact amino acetonitrile emission toward Sgr B2(M) or any cold, extended emission toward Sgr B2, with column-density upper limits of 6×10^{15} and $3 \times 10^{12-14}$ cm^{-2}, respectively.
Conclusions. Based on our amino acetonitrile detection toward Sgr B2(N) and a comparison to the pair methylcyanide/acetic acid both detected in this source, we suggest that the column density of both glycine conformers in Sgr B2(N) is well below the best upper limits published recently by other authors, and probably below the confusion limit in the 1-3 mm range. Accepted by Astronomy & Astrophysics http://de.arxiv.org/abs/0801.3219

Protostellar collapse: A comparison between SPH and AMR calculations

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The development of parallel supercomputers allows today the detailed study of the collapse and the fragmentation of prestellar cores with increasingly accurate numerical simulations. Thanks to the advances in sub-millimeter observations, a wide range of observed initial conditions enable us to study the different modes of low-mass star formation. The challenge for the simulations is to reproduce the observational results. Two main numerical methods, namely AMR and SPH, are widely used to simulate the collapse and the fragmentation of prestellar cores. We compare thoroughly these two methods within their standard framework. We use the AMR code RAMSES and the SPH code DRAGON. Our physical model is as simple as possible and consists of an isothermal sphere rotating around the z-axis. We first study the conservation of angular momentum as a function of the resolution. Then, we explore a wide range of simulation parameters to study the fragmentation of prestellar cores. There seems to be a convergence between the two methods, provided resolution in each case is sufficient. Resolution criteria adapted to our physical cases, in terms of resolution per Jeans mass, for an accurate description of the formation of protostellar cores are deduced from the present study. This convergence is encouraging for future work in simulations of low-mass star formation, providing the aforementioned criteria are fulfilled.

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http://www-dapnia.cea.fr/Projets/COAST/paper_amrvssph.pdf

Ethynyl (C_2H) in massive star formation: Tracing the initial conditions?

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APEX single-dish observations at sub-millimeter wavelengths toward a sample of massive star-forming regions reveal that C_2H is almost omni-present toward all covered evolutionary stages from Infrared Dark Clouds via High-Mass Protostellar Objects to Ultracompact H II regions. High-resolution data from the Submillimeter Array toward one hot-core like High-Mass Protostellar Object show a shell-like distribution of C_2H with a radius of $\sim$9000 AU around the central submm peak position. These observed features are well reproduced by a 1D cloud model with power-law density and temperature distributions and a gas-grain chemical network. The reactive C_2H radical (ethynyl) is abundant from the onset of massive star formation, but later it is rapidly transformed to other molecules in the core center. In the outer cloud regions the abundance of C_2H remains high due to constant replenishment of elemental carbon from CO being dissociated by the interstellar UV photons. We suggest that C_2H may be a molecule well suited to study the initial conditions of massive star formation.

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http://www.mpia.de/homes/beuther/papers.html

ATCA 3 mm observations of NGC6334I and I(N): dense cores, outflows and an UCHII region

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Aims: Investigation of the dense gas, the outflows and the continuum emission from the massive twin cores NGC6334I and I(N) at high spatial resolution.
Methods: We imaged the region with the Australia Telescope Compact Array (ATCA) at 3.4mm wavelength in continuum as well as CH3CN(5_K-4_K) and HCN(1-0) spectral line emission.
Results: While the continuum emission in NGC6334I mainly traces the UCHII region, toward NGC6334I(N) we detect line emission from four of the previously identified dust continuum condensations that are of protostellar or pre-stellar nature. The CH3CN(5_K-4_K) lines are detected in all K-components up to energies of 128K above ground toward two protostellar condensations in both regions. We find line-width increasing with increasing K for all sources, which indicates a higher degree of internal motions closer to the central protostars. Toward the main mm and CH3CN source in NGC6334I we identify a velocity gradient approximately perpendicular to the large-scale molecular outflow. This may be interpreted as a signature of an accretion disk, although other scenarios, e.g., an unresolved double source, could produce a similar signature as well. No comparable signature is found toward any of the other sources. HCN does not trace the dense gas well but it is dominated by the molecular outflows. While the outflow in NGC6334I exhibits a normal Hubble-law like velocity structure, the data indicate a precessing outflow close to the plane of the sky for NGC6334I(N). Furthermore, we observe a wide ($\sim$15.4km/s) HCN absorption line, much broader than the previously observed CH3OH and NH3 absorption lines. Several explanations for the difference are discussed.

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http://www.mpia.de/homes/beuther/papers.html

The c2d Spitzer Spectroscopic Survey of Ices Around Low-Mass Young Stellar Objects: I. H_2O and the 5-8 μm Bands

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With the goal to study the physical and chemical evolution of ices in solar-mass systems, a spectral survey is conducted of a sample of 41 low luminosity YSOs ($L \sim 0.1 - 10$ L$_\odot$) using 5–38 μm Spitzer Space Telescope and 3–4 μm ground-based spectra. The sample is complemented with previously published Spitzer spectra of background stars and with ISO spectra of well studied massive YSOs ($L \sim 10^5$ L$_\odot$). This paper focuses on the origin of the prominent absorption features in the 5-8 μm spectral region. The long-known 6.0 and 6.85 μm bands are detected toward all sources, with the Class 0-type low mass YSOs showing the deepest bands ever observed. In almost all sources the 6.0 μm band is deeper, by up to a factor of 3, than expected from the bending mode of pure solid H_2O, based on the optical depths of the 3.0 μm stretching and 13 μm libration modes. The depth and shape variations of the remaining 5–7 μm absorption indicate that it consists of 5 independent components, which, by comparison to laboratory studies, must be from at least 8 different carriers. Together with information from the 3-4 μm spectra and the additionally detected weak 7.25, 7.40, 9.0, and 9.7 μm features it is argued that overlapping bands of simple species are responsible for much of the absorption in the 5-7 μm region, at abundances of 1-30% for CH_3OH, 3-8% for NH_3, 1-5% for HCOOH, ∼6% for H_2CO, and ∼0.3% for $HCOO^-$ with respect to solid H_2O. The 6.85 μm band likely consists of one or two carriers, of which one is less volatile than H_2O because its abundance relative to H_2O is enhanced at lower $H_2O/\tau_{9.7}$ ratios. It does not survive in the diffuse interstellar medium (ISM), however. The similarity of the 6.85 μm bands for YSOs and background stars indicates that its carrier(s) must be formed early in the molecular cloud evolution. If an NH_4^+ salt is the carrier its abundance with respect to solid H_2O is typically 7%, and low temperature acid-base chemistry or cosmic ray induced reactions must have been involved in its formation. Possible origins are discussed for the carrier of an enigmatic, very broad absorption between 5 and 8 μm. It shows large depth variations toward both low- and high-mass YSOs. Weak evidence is found that it correlates with temperature tracers. Finally, all the phenomena observed for ices toward massive YSOs are also observed toward low mass YSOs, indicating that processing of the ices by internal ultraviolet radiation fields is a minor factor in the early chemical evolution of the ices.

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http://spider.ipac.caltech.edu/∼aboogert/spitzer_iceinv_preprint.pdf

Mixing in the Solar Nebula: Implications for Isotopic Heterogeneity and Large-Scale Transport of Refractory Grains

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The discovery of refractory grains amongst the particles collected from Comet 81P/Wild 2 by the Stardust spacecraft (Brownlee et al. 2006) provides the ground truth for large-scale transport of materials formed in high temperature regions close to the protosun outward to the comet-forming regions of the solar nebula. While accretion disk models driven by a generic turbulent viscosity have been invoked as a means to explain such large-scale transport, the detailed physics behind such an "alpha" viscosity remains unclear. We present here an alternative physical mechanism for large-scale transport in the solar nebula: gravitational torques associated with the transient spiral arms in a marginally gravitationally unstable disk, of the type that appears to be necessary to form gas giant planets. Three dimensional models are presented of the time evolution of self-gravitating disks, including radiative transfer and detailed equations of state, showing that small dust grains will be transported upstream and downstream (with respect to the mean inward flow of gas and dust being accreted by the central protostar) inside the disk on time scales of less than 1000 yr inside 10 AU. These models furthermore show that any initial spatial heterogeneities present (e.g., in short-lived isotopes such as ^{26}Al) will be homogenized by disk mixing down to a level of $\sim 10\%$, preserving the use of short-lived isotopes as accurate nebular chronometers, while simultaneously allowing for the spread of stable oxygen isotope ratios. This finite level of nebular spatial heterogeneity appears to be related to the coarse mixing achieved by spiral arms, with radial widths of order 1 AU, over time scales of $\sim$ 1000 yrs.

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Preprint available at http://www.dtm.ciw.edu/boss/ftp/tendisk/

Flux-Limited Diffusion Approximation Models of Giant Planet Formation by Disk Instability

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Both core accretion and disk instability appear to be required as formation mechanisms in order to explain the entire range of giant planets found in extrasolar planetary systems. Disk instability is based on the formation of clumps in a marginally-gravitationally unstable protoplanetary disk. These clumps can only be expected to contract and survive to become protoplanets if they are able to lose thermal energy through a combination of convection and radiative cooling. Here we present several new three dimensional, radiative hydrodynamics models of self-gravitating protoplanetary disks, where radiative transfer is handled in the flux-limited diffusion approximation. We show that while the flux-limited models lead to higher midplane temperatures than in a diffusion approximation model without the flux-limiter, the difference in temperatures does not appear to be sufficiently high to have any significant effect on the formation of self-gravitating clumps. Self-gravitating clumps form rapidly in the models both with and without the flux-limiter. These models suggest that the reason for the different outcomes of numerical models of disk instability by different groups cannot be attributed solely to the handling of radiative transfer, but rather appears to be caused by a range of numerical effects and assumptions. Given the observational imperative to have disk instability form at least some extrasolar planets, these models imply that disk instability remains as a viable giant planet formation mechanism.

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Preprint available at http://www.dtm.ciw.edu/boss/ftp/fluxlim

Multi-conjugate adaptive optics images of the Trapezium cluster

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Context. Multi-conjugate adaptive optics (MCAO) combine the advantages of both standard adaptive optics, which provide high contrast and high spatial resolution, and of wide field imaging ($\approx 1'$). Up to recently, MCAO for astronomy was limited to laboratory experiments. In this paper, we present the first scientific results obtained with the first MCAO instrument.
Aims. We present a new study of the Trapezium cluster using deep MCAO images with a field of view of $1' \times 1'$ obtained at the VLT.
Methods. We used deep J, H, and K_s images recently obtained with the prototype MCAO facility MAD at the VLT to search for new members and new multiple systems in the Trapezium cluster. On bright targets (Ks$\approx$9 mag), these images allow us to reach ΔKs$\approx$6 mag as close as $0''.4$.
Results. We report detection of 128 sources, including 10 new faint objects in the magnitude range between $16.1 < K$s < 17.9 mag. In addition to all previously known multiple systems with separations greater than $0''.1$, we confirm the multiplicity of TCC-055. We also report the detection in J, H, and Ks of a very red extended embedded protostellar object, HC 419, previously detected only in the thermal infrared.
Conclusions. Analysis of the first MCAO images obtained on the sky demonstrates not only the technical feasibility of MCAO, but also its great potential and versatility in terms of scientific output.

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Eccentricity growth of planetesimals in a self-gravitating protoplanetary disc

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We investigate the orbital evolution of planetesimals in a self-gravitating circumstellar disc in the size regime ($\sim 1-5000$ km) where the planetesimals behave approximately as test particles in the disc's non-axisymmetric potential. We find that the particles respond to the stochastic, regenerative spiral features in the disc by executing large random excursions (up to a factor of two in radius in ~ 1000 years), although typical random orbital velocities are of order one tenth of the Keplerian speed. The limited time frame and small number of planetesimals modeled does not permit us to discern any *net* direction of planetesimal migration. Our chief conclusion is that the high eccentricities (~ 0.1) induced by interaction with spiral features in the disc is likely to be highly unfavourable to the collisional growth of planetesimals in this size range while the disc is in the self-gravitating regi me. Thus *if*, as recently argued by Rice et al 2004, 2006, the production of planetesimals gets under way when the disc is in the self-gravitating regime (either at smaller planetesimal size scales, where gas drag is important, or via gravitational fragmentation of the solid component), then the planetesimals thus produced would not be able to grow collisionally until the disc ceased to be self-gravitating. It is unclear, however, given the large amplitude excursions undergone by planetesimals in the self-gravitating disc, whether they would be retained in the disc throughout this period, or whether they would instead be lost to the central star.

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Oscillating Starless Cores: Nonlinear Regime

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In a previous paper, we modeled the oscillations of a thermally supported (Bonnor-Ebert) sphere as nonradial, linear perturbations following a standard analysis developed for stellar pulsations. The predicted column density variations and molecular spectral line profiles are similar to those observed in the Bok globule B68, suggesting that the motions in some starless cores may be oscillating perturbations on a thermally supported equilibrium structure. However, the linear analysis is unable to address several questions, among them the stability and lifetime of the perturbations. In this paper, we simulate the oscillations using a threedimensional numerical hydrodynamic code. We find that the oscillations are damped predominantly by nonlinear mode coupling, and the damping timescale is typically many oscillation periods, corresponding to a few million years, and persisting over the inferred lifetime of globules.

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Dynamical parallax of σ Ori AB: mass, distance and age

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The massive OB-type binary σ Ori AB is in the centre of the very young σ Orionis cluster. I have computed the most probable distances and masses of the binary for several ages using a dynamical parallax-like method. It incorporates the BVRIH-band apparent magnitudes of both components, precise orbital parameters, interstellar extinction and a widely used grid of stellar models from the literature, Kepler's third law and a χ^2 minimization. The derived distance is 334^{+25}_{-22} pc for an age of 3 ± 2 Ma; larger ages and distances are unlikely. The masses of the primary and the secondary lie on the approximate intervals 16-20 and 10-12 $M_\odot$, respectively. I also discuss the possibility of σ Ori AB being a triple system at $\sim$ 385 pc. These results will help to constrain the properties of young stars and substellar objects in the σ Orionis cluster.

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Kinematics of solid particles in a turbulent protoplanetary disc

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We perform numerical simulations of solid particle motion in a shearing box model of a protoplanetary disc. The accretion flow is turbulent due to the action of the magnetorotational instability. Aerodynamic drag on the particles is modelled using the Epstein law with the gas velocity interpolated to the particle position. The effect of the magnetohydrodynamic turbulence on particle velocity dispersions is quantified for solids of different stopping times t_s, or equivalently, different sizes. The anisotropy of the turbulence is reflected upon the dispersions of the particle velocity components, with the radial component larger than both the azimuthal and vertical components for particles larger than
sim10 cm (assuming minimum-mass solar nebula conditions at 5 AU). The dispersion of the particle velocity magnitude, as well as that of the radial and azimuthal components, as functions of stopping time, agree with previous analytical results for isotropic turbulence. The relative speed between pairs of particles with the same value of t_s decays faster with decreasing separation than in the case of solids with different stopping time. Correlations in the particle number density introduce a non-uniform spatial distribution of solids in the 10 to 100 cm size range. Any clump of particles is disrupted by the turbulence in less than one tenth on an orbital period, and the maximally concentrated clumps are stable against self-gravitational collapse. Accepted by Monthly Notices of the Royal Astronomical Society
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The Distribution of Stellar Mass in the Pleiades

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As part of an effort to understand the origin of open clusters, we present a statistical analysis of the currently observed Pleiades. Starting with a photometric catalog of the cluster, we employ a maximum likelihood technique to determine the mass distribution of its members, including single stars and both components of binary systems. We find that the overall binary fraction for unresolved pairs is 68 percent.. Extrapolating to include resolved systems, this fraction climbs to about 76 percent, significantly higher than the accepted field-star result. Both figures are sensitive to the cluster age, for which we have used the currently favored value of 125 Myr. The primary and secondary masses within binaries are correlated, in the sense that their ratios are closer to unity than under the hypothesis of random pairing. We map out the spatial variation of the cluster's projected and three-dimensional mass and number densities. Finally, we revisit the issue of mass segregation in the Pleiades. We find unambiguous evidence of segregation, and introduce a new method for quantifying it. Accepted by The Astrophysical Journal, May 1, 2008

UV Radiation Fields Produced by Young Embedded Star Clusters

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A large fraction of stars form within young embedded clusters, and these environments produce a substantial ultraviolet (UV) background radiation field, which can provide feedback on the star formation process. To assess the possible effects of young stellar clusters on the formation of their constituent stars and planets, this paper constructs the expected radiation fields produced by these clusters. We include both the observed distribution of cluster sizes N in the solar neighborhood and an extended distribution that includes clusters with larger N. The paper presents distributions of the FUV and EUV luminosities for clusters with given stellar membership N, distributions of FUV and EUV luminosity convolved over the expected distribution of cluster sizes N, and the corresponding distributions of FUV and EUV fluxes. These flux distributions are calculated both with and without the effects of extinction. Finally, we consider the effects of variations in the stellar initial mass function on these radiation fields. Taken together, these results specify the distributions of radiation environments that forming solar systems are expected to experience.

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The Diverse Stellar Populations of the W3 Starforming Complex

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An $\sim$800 arcmin^2 mosaic image of the W3 star-forming complex obtained with the Chandra XRay Observatory gives a valuable new view of the spatial structure of its young stellar populations. The Chandra image reveals $\sim$1300 faint X-ray sources, most of which are premain-sequence (PMS) stars in the cloud. Some, but not all, of the high-mass stars producing hypercompact and ultracompact H II (UC H II) regions are also seen, as reported in a previous study. The Chandra images reveal three dramatically different embedded stellar populations. The W3 Main cluster extends over 7 pc with $\sim$900 X-ray stars in a nearly spherical distribution centered on the well-studied UC H II regions and high-mass protostars. The cluster surrounding the prototypical UC H II region W3(OH) shows a much smaller ($\leq$0.6 pc), asymmetrical, and clumpy distribution of $\sim$50 PMS stars. The massive star ionizing the W3 North H II region is completely isolated without any accompanying PMS stars. In W3 Main, the inferred ages of the widely distributed PMS stars are significantly older than the inferred ages of the central OB stars illuminating the UC H II regions.

We suggest that different formation mechanisms are necessary to explain the diversity of the W3 stellar populations: cluster-wide gravitational collapse with delayed OB star formation in W3 Main, collect-and-collapse triggering by shock fronts in W3(OH), and a runaway O star or isolated massive star formation in W3 North.

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Highly deuterated pre-stellar cores in a high-mass star formation region

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Aims. We have observed the deuterated gas in the high-mass star formation region IRAS 05345+3157 at high-angular resolution, in order to determine the morphology and the nature of this gas.
Methods. We have mapped the N_2H^+ (1-0) line with the Plateau de Bure Interferometer, and the N_2D^+ (3-2) and N_2H^+ (3-2) lines with the Submillimeter Array.
Results. We have detected two condensations in N_2D^+, with masses of ∼2-3 and ∼9 $M_\odot$ and diameters of 0.05 and 0.09 pc, respectively. The high deuterium fractionation (∼0.1) and the line parameters of the N_2D^+ condensations indicate that they are probably low- to intermediate-mass pre-stellar cores, even though other scenarios are possible.

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Time Variation in G24.78+0.08 A1: Evidence for an Accreting Hypercompact H II Region?

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Over a timescale of a few years, an observed change in the optically thick radio continuum flux can indicate whether an unresolved H II region around a newly formed massive star is changing in size. In this Letter we report on a study of archival VLA observations of the hypercompact H II region G24.78+0.08 A1 that shows a decrease of ∼ 45 % in the 6-cm flux over a 5 year period. Such a decrease indicates a contraction of ∼ 25 % in the ionized radius and could be caused by an increase in the ionized gas density if the size of the H II region is determined by a balance between photoionization and recombination. This finding is not compatible with continuous expansion of the H II region after the end of accretion onto the ionizing star, but is consistent with the hypothesis of gravitational trapping and ionized accretion flows if the mass accretion rate is not steady.

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Growth and Migration of Solids in Evolving Protostellar Disks. I. Methods and Analytical Tests

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This series of papers investigates the early stages of planet formation by modeling the evolution of the gas and solid content of protostellar disks from the early T Tauri phase until complete dispersal of the gas. In this first paper, I present a new set of simplified equations modeling the growth and migration of various species of grains in a gaseous protostellar disk evolving as a result of the combined effects of viscous accretion and photoevaporation from the central star. Using the assumption that the grain-size distribution function always maintains a power-law structure approximating the average outcome of the exact coagulation/shattering equation, the model focuses on the calculation of the growth rate of the largest grains only. The coupled evolution equations for the maximum grain size, the surface density of the gas, and the surface density of solids are then presented and solved self-consistently using a standard dimensional formalism. I show that the global evolution of solids is controlled by a leaky reservoir of small grains at large radii, and propose an empirically derived evolution equation for the total mass of solids, which can be used to estimate the total heavy-element retention efficiency in the planet formation paradigm. Detailed comparisons with SED observations are presented in a following paper.

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Accretion properties of T Tauri stars in σ Ori

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Accretion disks around young stars evolve in time with time scales of few million years. We present here a study of the accretion properties of a sample of 35 stars in the ~ 3 million year old star-forming region σ Ori. Of these, 31 are objects with evidence of disks, based on their IR excess emission. We use near-IR hydrogen recombination lines (Paγ) to measure their mass accretion rate. We find that the accretion rates are significantly lower in σ Ori than in younger regions, such as ρ Oph, consistently with viscous disk evolution. The He I 1.083 μm line is detected (either in absorption or in emission) in 72% of the stars with disks, providing evidence of accretion-powered activity also in very low accretors, where other accretion indicators dissapear.

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The Stellar Population and Origin of the Mysterious High-Latitude Star-forming Cloud CG 12

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The mysterious high Galactic latitude cometary globule CG 12 has been observed with the ACIS detector on board the Chandra X-Ray Observatory. We detect 128 X-ray sources, of which half are likely young stars formed within the globule's head. This new population of $\gtrsim 50$ T Tauri stars and one new embedded protostar is far larger than the previously reported few intermediate-mass and two protostellar members of the cloud. Most of the newly discovered stars have masses 0.2-0.7 $M_{\odot}$, and 9%-15% have K-band excesses from inner protoplanetary disks. X-ray properties provide an independent distance estimate consistent with CG 12's unusual location 200 pc above the Galactic plane. The star formation efficiency in CG 12 appears to be 15%-35%, far above that seen in other triggered molecular globules. The median photometric age found for the T Tauri population assuming Siess et al. (2000) isochrones is $\sim$4 Myr with a large spread of $< 1 - 20$ Myr and ongoing star formation in the molecular cores. The stellar age and spatial distributions are inconsistent with a simple radiation-driven implosion (RDI) model and suggest either that CG 12 is an atypically large shocked globule or that it has been subject to several distinct episodes of triggering and ablation. We report a previously unnoticed group of B-type stars northwest of CG 12 that may be the remnants of an OB association that produced multiple supernova explosions that could have shocked and ablated the cloud over a 15-30 Myr period. HD 120958 (B3e), the most luminous member of the group, may be currently driving an RDI shock into the CG 12 cloud.

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Physical conditions in CaFe interstellar clouds

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Interstellar clouds that exhibit strong Ca I and Fe I lines are called CaFe clouds. Ionisation equilibrium equations were used to model the column densities of Ca II, Ca I, K I, Na I, Fe I and Ti II in CaFe clouds. We find that the chemical composition of CaFe clouds is solar and that there is no depletion into dust grains. CaFe clouds have high electron densities, $n_e \approx 1$ cm^{-3}, that lead to high column densities of neutral Ca and Fe.

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Results of the ROTOR-program II. The long-term photometric variability of weak-line T Tauri stars

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Context. T Tauri stars exhibit variability on all timescales, whose origin is still debated. On WTTS the variability is fairly simple and attributed to long-lived, ubiquitous cool spots.
Aims. e investigate the long term variability of WTTS, extending up to 20 years in some cases, characterize it statistically and discuss its implications for our understanding of these stars.
Methods. We have obtained a unique, homogeneous database of photometric measurements for WTTS extending up to 20 years. It contains more than 9 000 UBV R observations of 48 WTTS. All the data were collected at Mount Maidanak Observatory (Uzbekistan) and they constitute the longest homogeneous record of accurate WTTS photometry ever assembled.
Results. Definitive rotation periods for 35 of the 48 stars are obtained. Phased light curves over 5 to 20 seasons are now available for analysis. Light curve shapes, amplitudes and colour variations are obtained for this sample and various behaviors exhibited, discussed and interpreted.
Conclusions. Our main conclusion is that most WTTS have very stable long term variability with relatively small changes of amplitude or mean light level. The long term variability seen reflects modulation in the cold spot distributions. Photometric periods are stable over many years, and the phase of minimum light can be stable as well for several years. On the long term, spot properties do change in subtle ways, leading to secular variations in the shape and amplitudes of the light curves.

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High Resolution Near-Infrared Spectroscopy of FUors and FUor-like stars

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We present new high resolution ($R \simeq 18,000$) near-infrared spectroscopic observations of a sample of classical FU Orionis stars (FUors) and other young stars with FUor characteristics that are sources of Herbig-Haro flows. Spectra are presented for the region $\lambda = 2.203 - 2.236$ μm which is rich in absorption lines sensitive to both effective temperatures and surface gravities of stars. Both FUors and FUor-like stars show numerous broad and weak unidentified spectral features in this region. Spectra of the $2.280 - 2.300$ μm region are also presented, with the 2.2935 μm v=2–0 CO absorption bandhead being clearly the strongest feature seen in the spectra all FUors and Fuor-like stars. A cross-correlation analysis shows that FUor and FUor-like spectra in the 2.203 – 2.236 μm region are not consistent with late-type dwarfs, giants, nor embedded protostars. The cross-correlations also show that the observed FUor-like Herbig-Haro energy sources have spectra that are substantively similar to those of FUors. Both object groups also have similar near-infrared colors. The large line widths and double-peaked nature of the spectra of the FUor-like stars are consistent with the established accretion disk model for FUors, also consistent with their near-infrared colors. It appears that young stars with FUor-like characteristics may be more common than projected from the relatively few known classical FUors.

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Grain Sedimentation in a Giant Gaseous Protoplanet

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We present a calculation of the sedimentation of grains in a giant gaseous protoplanet such as that resulting from a disk instability of the type envisioned by Boss (1998). Boss (1998) has suggested that such protoplanets would form cores through the settling of small grains. We have tested this suggestion by following the sedimentation of small silicate grains as the protoplanet contracts and evolves. We find that during the course of the initial contraction of the protoplanet, which lasts some 4×10^5 years, even very small ($> 1\mu$m) silicate grains can sediment to create a core both for convective and non-convective envelopes, although the sedimentation time is substantially longer if the envelope is convective, and grains are allowed to be carried back up into the envelope by convection. Grains composed of organic material will mostly be evaporated before they get to the core region, while water ice grains will be completely evaporated. These results suggest that if giant planets are formed via the gravitational instability mechanism, a small heavy element core can be formed due to sedimentation of grains, but it will be composed almost entirely of refractory material. Including planetesimal capture, we find core masses between 1 and 10 $M_\oplus$, and a total high-Z enhancement of ~ 40 $M_\oplus$. The refractories in the envelope will be mostly water vapor and organic residuals.

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History and Spectroscopy of EXor Candidates

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The EXors are T Tauri stars that occasionally flare up from minimum light, apparently as the result of a massive infall of circumstellar material. The prototype, EX Lupi, is the only example that has been examined spectroscopically in any detail, so this paper surveys what can be gleaned from the literature about five candidate EXors, and describes new observations. The aim is to clarify the nature of these objects, and to determine whether they bear a convincing resemblance to EX Lup itself. The spectroscopy was carried out with the HIRES spectrograph (R = 48,000) at the Keck I telescope between 2004 and 2007. Three of the stars examined are in or near the Orion Nebula (NY, V1118, and V1143 Ori), while V1184 Tau is in the molecular cloud CB34, and V350 Cep is at the edge of the young cluster NGC 7129. The spectrograms were obtained at random times, and there was no coordinated photometry, but it was possible to conclude that the three Orion stars can be considered conventional EXors. At minimum light, they resemble K- or early M-type dwarfs plus a T Tauri-like emission spectrum, but no spectral characteristic was found that set them aside from ordinary T Tauri stars. Such a signature might be found in deep-infrared photometry, but they do not stand out at 2 μm. Several interesting spectroscopic phenomena were observed, however, notably the appearance of the λ6707 line in emission in V1118 Ori near maximum, and the detection of simultaneous infall and outflow at the Na I D_{12} lines in several EXors (although that has also been reported in several Classical T Tauri stars). V1184 Tau is

not an EXor: it is unclear if its activity is repetitive. Nor is V350 Cep: after recovering from a deep minimum about 1975, it has since remained near maximum for nearly three decades.

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UV excess measures of accretion onto young very low-mass stars and brown dwarfs

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Low-resolution spectra from 3000–9000 Å of young low-mass stars and brown dwarfs were obtained with LRIS on *Keck I*. The excess UV and optical emission arising in the Balmer and Paschen continua yields mass accretion rates ranging from 2×10^{-12} to 10^{-8} $M_\odot$ yr^{-1}. These results are compared with *HST*/STIS spectra of roughly solar-mass accretors with accretion rates that range from 2×10^{-10} to 5×10^{-8} $M_\odot$ yr^{-1}. The weak photospheric emission from M-dwarfs at < 4000 Å leads to a higher contrast between the accretion and photospheric emission relative to higher-mass counterparts. The mass accretion rates measured here are systematically $\sim 4-7$ times larger than those from Hα emission line profiles, with a difference that is consistent with but unlikely to be explained by the uncertainty in both methods. The accretion luminosity correlates well with many line luminosities, including high Balmer and many He I lines. Correlations of the accretion rate with Hα 10% width and line fluxes show a large amount of scatter. Our results and previous accretion rate measurements suggest that $\dot{M} \propto M^{1.87 \pm 0.26}$ for accretors in the Taurus Molecular Cloud.

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Spitzer Observations of the Orion OB1 Association: Disk Census in the LowMass Stars

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We present new Spitzer observations of two fields in the Orion OB1 association. We report IRAC/MIPS observations for 115 confirmed members and 41 photometric candidates of the $\sim$ 10 Myr 25 Orionis aggregate in the OB1a subassociation, and 106 confirmed members and 65 photometric candidates of the 5 Myr region located in the OB1b subassociation. The 25 Orionis aggregate shows a disk frequency of 6%, while the field in the OB1b subassociation shows a disk frequency of 13%. Combining IRAC, MIPS, and 2MASS photometry, we place stars bearing disks in several classes: those with optically thick disks (class II systems), with an inner transitional disks (transitional disk candidates), and with "evolved disks"; the last exhibit smaller IRAC/MIPS excesses than class II systems. In all, we identify one transitional disk candidate in the 25 Orionis aggregate and three in the OB1b field; this represents 10% of the diskbearing stars, indicating that the transitional disk phase can be relatively fast. We find that the frequency of disks is a function of the stellar mass, suggesting a maximum around stars with spectral type M0. Comparing the infrared excess in the IRAC bands among several stellar groups, we find that inner disk emission decays with stellar age, showing a correlation with the respective disk frequencies. The disk emission at the IRAC and MIPS bands in several stellar groups indicates that disk dissipation takes place faster in the inner region of the disks. Comparison with models of irradiated accretion disks, computed with several degrees of settling, suggests that the decrease in the overall accretion rate observed in young stellar groups is not sufficient to explain the weak disk emission observed in the IRAC bands for diskbearing stars with ages 5 Myr or older; larger degrees of dust settling are necessary to explain these objects.

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The use of genetic algorithms to model protoplanetary discs

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The protoplanetary discs of T Tauri and Herbig Ae/Be stars have previously been studied using geometric disc models to fit their spectral energy distribution (SED). The simulations provide a means to reproduce the signatures of various circumstellar structures, which are related to different levels of infrared excess. With the aim of improving our previous model, which assumed a simple flat-disc configuration, we adopt here a reprocessing flared-disc model that assumes hydrostatic, radiative equilibrium. We have developed a method to optimize the parameter estimation based on genetic algorithms (GAs). This paper describes the implementation of the new code, which has been applied to Herbig stars from the Pico dos Dias Survey catalogue, in order to illustrate the quality of the fitting for a variety of SED shapes. The star AB Aur was used as a test of the GA parameter estimation, and demonstrates that the new code reproduces successfully a canonical example of the flared-disc model. The GA method gives a good quality of fit, but the range of input parameters must be chosen with caution, as unrealistic disc parameters can be derived. It is confirmed that the flared-disc model fits the flattened SEDs typical of Herbig stars; however, embedded objects (increasing SED slope) and debris discs (steeply decreasing SED slope) are not well fitted with this configuration. Even considering the limitation of the derived parameters, the automatic process of SED fitting provides an interesting tool for the statistical analysis of the circumstellar luminosity of large samples of young stars.

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Toward a Deterministic Model of Planetary Formation. IV. Effects of Type I Migration

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In a further development of a deterministic planet formation model (Ida & Lin), we consider the effect of type I migration of protoplanetary embryos due to their tidal interaction with their nascent disks. During the early phase of protostellar disks, although embryos rapidly emerge in regions interior to the ice line, uninhibited type I migration leads to their efficient self-clearing. But embryos continue to form from residual planetesimals, repeatedly migrate inward, and provide a main channel of heavy-element accretion onto their host stars. During the advanced stages of disk evolution (a few Myr), the gas surface density declines to values comparable to or smaller than that of the minimum mass nebula model, and type I migration is no longer effective for Mars-mass embryos. Over wide ranges of initial disk surface densities and type I migration efficiencies, the surviving population of embryos interior to the ice line has a total mass of several $M_\oplus$. With this reservoir, there is an adequate inventory of residual embryos to subsequently assemble into rocky planets similar to those around the Sun. However, the onset of efficient gas accretion requires the emergence and retention of cores more massive than a few $M_\oplus$ prior to the severe depletion of the disk gas. The formation probability of gas giant planets and hence the predicted mass and semimajor axis distributions of extrasolar gas giants are sensitively determined by the strength of type I migration. We suggest that the distributions consistent with observations can be reproduced only if the actual type I migration timescale is at least an order of magnitude longer than that deduced from linear theories.

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The Monitor project: rotation of low-mass stars in the open cluster NGC 2547

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We report on the results of an I-band time-series photometric survey of NGC 2547 using the MPG/ESO 2.2-m telescope with Wide Field Imager, achieving better than 1 per cent photometric precision per data point over 14$\lesssim$ I $\lesssim$18. Candidate cluster members were selected from a V versus V I colourmagnitude diagram over 12.5 < V < 24 (covering masses from 0.9 $M_\odot$ down to below the brown dwarf limit), finding 800 candidates, of which we expect ∼330 to be real cluster members, taking into account contamination from the field (which is most severe at the extremes of our mass range). Searching for periodic variations in these gave 176 detections over the mass range 0.1$\lesssim$ $M/M_\odot$ $\lesssim$0.9. The rotation period distributions were found to show a clear mass-dependent morphology, qualitatively intermediate between the distributions obtained from similar surveys in NGC 2362 and 2516, as would be expected from the age of this cluster. Models of the rotational evolution were investigated, finding that the evolution from NGC 2362 to 2547 was qualitatively reproduced (given the uncertainty in the age of NGC 2547) by solid body and core-envelope decoupled models from our earlier NGC 2516 study without need for significant modification.

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Near-Infrared Silhouette Object Survey in M17

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To study how the structure of the envelopes of young stellar objects (YSOs) evolve, we carried out a deep JHK'-band imaging survey of the M17 star-forming region using a near-infrared camera and the Infrared Camera and Spectrograph with adaptive optics mounted on the Subaru Telescope. In this survey, we found 51 dark silhouettes against bright near-infrared nebula emissions as background lights. They are regarded as envelopes associated with YSOs due to their size and association with the YSOs. We derived size, morphology, extinction, and mass for each silhouette envelope. The average mass of the envelopes was ~ 0.02 $M_\odot$, and the radius ranged from 1.5″ to 2.8″ (2250-4200 AU). We compared the properties of envelopes with the properties of the central YSO derived from color-color and color-magnitude diagrams. The radius and the mass of the envelope were found to decrease with the decrease in infrared excess, consistent with the widely accepted view in which the envelope accretes onto the central star/disk system during its evolution from Class I to Class II. However, the envelope still exists around the Class II object for which accretion is barely discernible, and it may have escaped detection due to its dimness. The envelope associated with Class II objects may not accrete onto the star or the disk, but it may dissipate in the future.

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Disks around Massive Young Stellar Objects: Are They Common?

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We present K-band polarimetric images of several massive young stellar objects at resolutions $\sim$ 0.1″-0.5″. The

polarization vectors around these sources are nearly centrosymmetric, indicating they are dominating the illumination of each field. Three out of the four sources show elongated lowpolarization structures passing through the centers, suggesting the presence of polarization disks. These structures and their surrounding reflection nebulae make up bipolar outflow/disk systems, supporting the collapse/accretion scenario as their low-mass siblings. In particular, S140 IRS 1 shows well-defined outflow cavity walls and a polarization disk which matches the direction of previously observed equatorial disk wind, thus confirming that the polarization disk is actually the circumstellar disk. To date, a dozen massive protostellar objects show evidence for the existence of disks; our work adds additional samples around massive young stellar objects equivalent to early B type stars.

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A Corona Australis cloud filament seen in NIR scattered light I. Comparison with extinction of background stars

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With current near-infrared (NIR) instruments the near-infrared light scattered from interstellar clouds can be mapped over large areas. The surface brightness carries information on the line-of-sight dust column density. Therefore, scattered light could provide an important tool to study mass distribution in quiescent interstellar clouds at a high, even sub-arcsecond resolution. We wish to confirm the assumption that light scattering dominates the surface brightness in all NIR bands. Furthermore, we want to show that scattered light can be used for an accurate estimation of dust column densities in clouds with AV in the range 1-15 mag . We have obtained NIR images of a quiescent filament in the Corona Australis molecular cloud. The observations provide maps of diffuse surface brightness in J, H, and Ks bands. Using the assumption that signal is caused by scattered light we convert surface brightness data into a map of dust column density. The same observations provide colour excesses for a large number of background stars. These data are used to derive an extinction map of the cloud. The two, largely independent tracers of the cloud structure are compared. In regions below Av 15 mag both diffuse surface brightness and background stars lead to similar column density estimates. The existing differences can be explained as a result of normal observational errors and bias in the sampling of extinctions provided by the background stars. There is no indication that thermal dust emission would have a significant contribution even in the Ks band. The results show that, below Av 15 mag , scattered light does provide a reliable way to map cloud structure. Compared with the use of background stars it can also in practice provide a significantly higher spatial resolution.

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Planet Formation around Stars of Various Masses: The Snow Line and the Frequency of Giant Planets

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We use a semianalytic circumstellar disk model that considers movement of the snow line through evolution of accretion and the central star to investigate how gas giant frequency changes with stellar mass. The snow line distance changes weakly with stellar mass; thus, giant planets form over a wide range of spectral types. The probability that a given star has at least one gas giant increases linearly with stellar mass from 0.4 to 3 $M_\odot$. Stars more massive than 3 $M_\odot$ evolve quickly to the main sequence, which pushes the snow line to 10-15 AU before protoplanets form and limits the range of disk masses that form giant planet cores. If the frequency of gas giants around solar mass stars is 6%, we predict occurrence rates of 1% for 0.4 $M_\odot$ stars and 10% for 1.5 $M_\odot$ stars. This result is largely insensitive to our assumed model parameters. Finally, the movement of the snow line as stars $\gtrsim$2.5 $M_\odot$ move to the main sequence may allow the ocean planets suggested by Léger et al. to form without migration.

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The Early Evolution of Massive Stars: Radio Recombination Line Spectra

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Velocity shifts and differential broadening of radio recombination lines are used to estimate the densities and velocities of the ionized gas in several hypercompact and ultracompact H II regions. These small H II regions are thought to be at their earliest evolutionary phase and associated with the youngest massive stars. The observations suggest that these H II regions are characterized by high densities, supersonic flows, and steep density gradients, consistent with accretion and outflows that would be associated with the formation of massive stars.

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Formation of Terrestrial Planets from Protoplanets. II. Statistics of Planetary Spin

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The final stage of terrestrial planet formation is known as the giant impact stage, where protoplanets collide with one another to form planets. The initial spin state of terrestrial planets is determined at this stage. We statistically investigate the spin parameters of terrestrial planets assembled from protoplanets using N-body simulations. As initial conditions, we adopt the oligarchic growth model of protoplanets. For the standard disk model, typically two Earth-sized planets form in the terrestrial planet region. We find that the spin angular velocity of the planets is well expressed by a Gaussian distribution, and their obliquity is well expressed by an isotropic distribution. The typical spin angular velocity is given by the critical spin angular velocity for rotational instability under the assumption of perfect accretion in collisions. We show the dependencies of the spin parameters on the initial protoplanet system parameters. The initial orbital separation and velocity anisotropy of protoplanets barely affect the spin parameters. The bulk density of protoplanets does not affect the obliquity distribution, while the spin angular velocity increases with the bulk density.

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A Massive Star-forming Infrared Loop around the Crab-like Supernova Remnant G54.1+0.3: Post-Main Sequence Triggered Star Formation?

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We report the discovery of a star-forming loop around the young, Crab-like supernova remnant (SNR) G54.1+0.3 using the AKARI infrared satellite. The loop consists of at least 11 young stellar objects (YSOs) embedded in a ringlike diffuse emission of radius $\sim 1'$. The YSOs are bright in the mid-infrared and are also visible in the Spitzer Space Telescope Galactic plane survey images. Their Spitzer colors are similar to those of Class II YSOs in [3.6] - [5.8] but significantly redder in [8] - [24], i.e., $0 <$ [3.6] - [5.8] < 1.2 and $5 <$ [8] - [24] < 9. Most of them have near-infrared counterparts in the 2MASS JHK_s images, and some of them have an optical counterpart too. Their JHK_S colors and magnitudes indicate that the YSOs are massive ($\gtrsim$10M$_\odot$) pre-main-sequence stars at the same distance to the SNR, i.e., 8 kpc, which supports the association of the star-forming loop with the SNR. The dereddened spectral energy distributions are similar to early Herbig Be stars, which are early B type pre-main-sequence stars with inner disks that have been destroyed. The confinement to a loop structure indicates that the YSOs are young, i.e., *lesssim*2 Myr. We propose that their formation is triggered by the progenitor star of G54.1+0.3, which has a mass of $\lesssim 15$ M$_\odot$. The triggering must have occurred near the end of the progenitor's life, possibly after it had evolved off the main sequence.

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A Minimum Column Density of 1 g cm^{-2} for Massive Star Formation

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Massive stars are very rare, but their extreme luminosities make them both the only type of young star we can observe in distant galaxies and the dominant energy sources in the universe today. They form rarely because efficient radiative cooling keeps most star-forming gas clouds close to isothermal as they collapse, and this favors fragmentation into stars $\lesssim 1\ M_\odot$. Heating of a cloud by accreting low-mass stars within it can prevent fragmentation and allow formation of massive stars, but what properties a cloud must have to form massive stars, and thus where massive stars form in a galaxy, has not yet been determined. Here we show that only clouds with column densities $\gtrsim 1$ g cm^{-2} can avoid fragmentation and form massive stars. This threshold, and the environmental variation of the stellar initial mass function (IMF) that it implies, naturally explain the characteristic column densities of massive star clusters and the difference between the radial profiles of Hα and UV emission in galactic disks. The existence of a threshold also implies that there should be detectable variations in the IMF with environment within the Galaxy and in the characteristic column densities of massive star clusters between galaxies, and that star formation rates in some galactic environments may have been systematically underestimated.

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http://www.astro.princeton.edu/∼krumholz/publications.html

Discovery of a Scattering Disk around the LowMass T Tauri Star FN Tauri

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We have discovered an optically thick, nearly face-on circumstellar disk around a single M5 classical T Tauri star, FN Tau, using the coronagraphic imager CIAO on the Subaru telescope. This is the least massive T Tauri star whose circumstellar structure has been directly imaged as a scattering disk. The surface brightness in the H band declines as a power law of $r^{-2.5\pm0.1}$ (110 AU $\leq r \leq$ 260 AU), suggesting that the disk is flared. The disk morphology appears to be relatively featureless except for an azimuthal asymmetry in the surface brightness, indicating that the disk is not perfectly face-on but is slightly tilted. The disk mass, derived from a simple disk emission model with previous photometry at optical to millimeter wavelengths, is ~ 0.007 $M_\odot$, 6% of the mass of the central star. The disk around FN Tau is one of the best targets for disk and planet formation studies around M stars.

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Probing the Turbulence Dissipation Range and Magnetic Field Strengths in Molecular Clouds

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We study the turbulent velocity dispersion spectra of the coexistent HCN and HCO^+ molecular species as a function of length scale in the M17 star-forming molecular cloud. We show that the observed downward shift of the ion's spectrum relative to that of the neutral is readily explained by the existence of an ambipolar diffusion range within which ion and neutral turbulent energies dissipate differently. We use these observations to evaluate this decoupling scale and show how to estimate the strength of the plane-of-the-sky component of the embedded magnetic field in a completely novel way.

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Near-infrared cross-dispersed spectroscopy of brown dwarf candidates in the Upper Sco association

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We present near-infrared (1.15-2.50 μm) medium-resolution (R = 1700) spectroscopy of a sample of 23 brown dwarf candidates in the young Upper Sco association. We confirm membership of 21 brown dwarfs based on their spectral shape, comparison with field dwarfs and presence of weak gravity-sensitive features. Their spectral types range from M8 to L2 with an uncertainty of a subclass, suggesting effective temperatures between 2700 and 1800 K with an uncertainty up to 300 K and masses in the 308 M_{Jup} range. Among the non-members, we have uncovered a field L2 dwarf at a distance of 120140 pc, assuming that it is single. The success rate of our photometric selection based on five photometric passbands and complemented partly by proper motion is over 90 per cent, a very promising result for future studies of the low-mass star and brown dwarf populations in young open clusters by the UKIDSS [UKIRT (United Kingdom Infrared Telescope) Infrared Deep Sky Survey] Galactic Cluster Survey. We observe a large dispersion in the magnitude versus spectral-type relation which is likely the result of the combination of several effects including age dispersion, extent and depth of the association, a high degree of multiplicity and the occurrence of discs.

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VLBA determination of the distance to nearby star-forming regions III. A preliminary distance to the Ophiuchus core with 4% accuracy

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The non-thermal 3.6 cm radio continuum emission from the young stars S1 and DoAr21 in the core of Ophiuchus, has been observed with the Very Long Baseline Array (VLBA) at 6 and 7 epochs, respectively, between June 2005 and August 2006. The typical separation between successive observations was 2 to 3 months. Thanks to the remarkably accurate astrometry delivered by the VLBA, the trajectory described by both stars on the plane of the sky could be traced very precisely, and modeled as the superposition of their trigonometric parallax and a uniform proper motion. The best fits yield distances to S1 and DoAr21 of $116.9^{+7.2}_{-6.4}$ and $121.9^{+5.8}_{-5.3}$, respectively. Combining these results, we estimate the mean distance to the Ophiuchus core to be $120.0^{+4.5}_{-4.2}$, a value consistent with several recent indirect determinations, but with a significantly improved accuracy of 4%. Both S1 and DoAr21 happen to be members of tight binary systems, but our observations are not frequent enough to properly derive the corresponding orbital parameters. This could be done with additional data, however, and would result in a significantly improved accuracy on the distance determination.

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SMA observations of young disks: separating envelope, disk, and stellar masses in class I YSOs

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CONTEXT: Young stars are born with envelopes, which in the early stages obscure the central (proto)star and circumstellar disk. In the Class I stage, the disks are still young, but the envelopes are largely dispersed. This makes the Class I sources ideal targets for studies of the early stages of disks.
AIMS: We aim to determine the masses of the envelopes, disks, and central stars of young stellar objects (YSOs) in the Class I stage.
METHODS: We observed the embedded Class I objects IRS 63 and Elias 29 in the rho Ophiuchi star-forming region with the Submillimeter Array (SMA) at 1.1 mm.
RESULTS: IRS 63 and Elias 29 are both clearly detected in the continuum, with peak fluxes of 459 and 47 mJy/beam, respectively. The continuum emission toward Elias 29 is clearly resolved, whereas IRS 63 is consistent with a point source down to a scale of 3 arcsec (400 AU). The SMA data are combined with single-dish data, and both disk masses of 0.055 and ¡= 0.007 MSun and envelope masses of 0.058 and ¡= 0.058 MSun are empirically determined for IRS 63 and Elias 29, respectively. The disk+envelope systems are modelled with the axisymmetric radiative-transfer code RADMC, yielding disk and envelope masses that differ from the empirical results by factors of a few. HCO+ J = 3-2 is detected toward both sources, HCN J = 3-2 is not. The HCO+ position-velocity diagrams are indicative of Keplerian rotation and allow an estimate of the mass of the central stars. For a fiducial inclination of 30 degrees, we find stellar masses of 0.37 +/- 0.13 MSun for IRS 63 and 2.5 +/- 0.6 MSun for Elias 29.
CONCLUSIONS: The sensitivity and spatial resolution of the SMA at 1.1 mm allow a good separation of the disks around Class I YSOs from their circumstellar envelopes and environments, and the spectral resolution makes it possible to resolve their dynamical structure and estimate the masses of the central stars. The ratios of the envelope and disk masses Menv/Mdisk are found to be 0.2 for IRS 63 and 6 for Elias 29. This is lower than the values for Class 0 sources, which have Menv/Mdisk >= 10, suggesting that this ratio is a tracer of the evolutionary stage of a YSO.

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The nature of HHL 73 from optical imaging and Integral Field Spectroscopy

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We present new results on the nature of the Herbig–Haro-like object 73 (HHL 73, also known as [G84b] 11) based on narrow-band CCD Hα and [S II] images of the HHL 73 field, and Integral Field Spectroscopy and radio continuum observations at 3.6 cm covering the emission of the HHL 73 object. The CCD images allow us to resolve the HHL 73 comet-shaped morphology into two components and a collimated emission feature of $\sim$ 4-arcsec long, reminiscent of a microjet. The IFS spectra of HHL 73 showed emission lines characteristic of the spectra of Herbig–Haro objects. The kinematics derived for HHL 73 are complex. The profiles of the [S II] $\lambda\lambda$6717, 6731 Å lines were well fitted with a model of three Gaussian velocity components peaking at $V_{\rm LSR} \simeq -100$, -20 and $+35$ km s^{-1}. We found differences among the spatial distribution of the kinematic components that are compatible with the emission from a bipolar outflow with two blueshifted (low- and high-velocity) components. Extended radio continuum emission at 3.6 cm was detected showing a distribution in close agreement with the HHL 73 redshifted gas. From the results discussed here, we propose HHL 73 to be a true HH object. *IRAS* 21432+4719, offset 30 arcsec northeast from the HHL 73 apex, could be tracing the exciting source of HHL 73, although the evidence is not conclusive.

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Two-component jet simulations I. Topological stability of analytical MHD outflow solutions

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Context. Observations of collimated outflows in young stellar objects indicate that several features of the jets can be understood by adopting the picture of a two-component outflow, wherein a central stellar component around the jet axis is surrounded by an extended disk wind. The precise contribution of each component may depend on the intrinsic physical properties of the YSO-disk system as well as its evolutionary stage.
Aims. This article reports a systematic separate investigation of these jet components via time-dependent simulations of two prototypical and complementary analytical solutions, each closely related to the properties of stellar outflows and disk winds. These models describe a meridionally and a radially self-similar exact solution of the steady-state, ideal hydromagnetic equations, respectively.
Methods. Using the PLUTO code to carry out the simulations, the study focuses on the topological stability of each of the two analytical solutions, which are successfully extended to all space by removing their singularities. In addition, their behavior and robustness over several physical and numerical modifications is extensively examined. Therefore, this work serves as the starting point for the analysis of the two-component jet simulations.
Results. It is found that radially self-similar solutions (disk winds) always reach a final steady-state while maintaining all their well-defined properties. The different ways to replace the singular part of the solution around the symmetry

axis, being a first approximation towards a two-component outflow, lead to the appearance of a shock at the super-fast domain corresponding to the fast magnetosonic separatrix surface. These conclusions hold true independently of the numerical modifications and/or evolutionary constraints that the models have undergone, such as starting with a sub-modified-fast initial solution or different types of heating/cooling assumptions. Furthermore, the final outcome of the simulations remains close enough to the initial analytical configurations, thus showing their topological stability. Conversely, the asymptotic configuration and the stability of meridionally self-similar models (stellar winds) is related to the heating processes at the base of the wind. If the heating is modified by assuming a polytropic relation between density and pressure, a turbulent evolution is found. On the other hand, adiabatic conditions lead to the replacement of the outflow by an almost static atmosphere.

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The Formation of the First Stars II. Radiative Feedback Processes and Implications for the Initial Mass Function

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We consider the radiative feedback processes that operate during the formation of the first stars, including the photodissociation of H_2, Lyman-α radiation pressure, formation and expansion of an HII region, and disk photoevaporation. These processes may inhibit continued accretion once the stellar mass has reached a critical value, and we evaluate this mass separately for each process. Photodissociation of H_2 in the local dark matter minihalo occurs relatively early in the growth of the protostar, but we argue this does not affect subsequent accretion since by this time the depth of the potential is large enough for accretion to be mediated by atomic cooling. However, neighboring starless minihalos can be affected. Ionization creates an HII region in the infalling envelope above and below the accretion disk. Lyman-α radiation pressure acting at the boundary of the HII region is effective at reversing infall from narrow polar directions when the star reaches $\sim 20-30 M_\odot$, but cannot prevent infall from other directions. Expansion of the HII region beyond the gravitational escape radius for ionized gas occurs at masses $\sim 50-100 M_\odot$, depending on the accretion rate and angular momentum of the inflow. However, again, accretion from the equatorial regions can continue since the neutral accretion disk has a finite thickness and shields a substantial fraction of the accretion envelope from direct ionizing flux. At higher stellar masses, $\sim 140 M_\odot$ in the fiducial case, the combination of declining accretion rates and increasing photoevaporation-driven mass loss from the disk act to effectively halt the increase in the protostellar mass. We identify this process as the mechanism that terminates the growth of Population III stars (i.e., stars with primordial composition) that have not been affected by prior star formation (Population III.1 stars). We discuss the implications of our results for the initial mass function of these stars. In the Appendix we develop approximate solutions to a number of problems relevant to the formation of the first stars: the effect of Rayleigh scattering on line profiles in media of very large optical depth; the intensity of Lyman-α radiation in very opaque media; an approximate determination of the radiative acceleration in terms of the gradient of a modified radiation pressure; the determination of the flux of radiation in a shell with an arbitrary distribution of opacity; and the vertical structure of an accretion disk supported by gas pressure with constant opacity.

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Evolution of Mid-Infrared Excess around Sun-like Stars: Constraints on Models of Terrestrial Planet Formation

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We report observations from the Spitzer Space Telescope regarding the frequency of 24 μm excess emission toward Sunlike stars. Our unbiased sample is composed of 309 stars with masses 0.72.2 $M_\odot$ and ages from <3 Myr to >3 Gyr that lack excess emission at wavelengths $\leq 8\mu$m. We identify 30 stars that exhibit clear evidence of excess emission from the observed 24 μm/8 μm flux ratio. The implied 24 μm excesses of these candidate debris disk systems range from 13% (the minimum detectable) to more than 100% compared to the expected photospheric emission. The frequency of systems with evidence for dust debris emitting at 24 μm ranges from 8.5%-19% at ages <300 Myr to <4% for older stars. The results suggest that many, perhaps most, Sunlike stars might form terrestrial planets.

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The Evolution of the Spectral Energy Distribution in Massive Young Stellar Objects

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The mechanism for the formation of massive stars is still a matter of fiery debate. It is not yet clear if it can be considered to be a scaled-up analogue of the low-mass star regime, or if there are additional agents like merging of lower-mass forming objects or accretion from initially unbound material. Most of the uncertainties come from the lack of diagnostic tools to evolutionary classify large samples of candidate massive protostellar objects that can then be studied in more detail. We want to verify if diagnostic tools like the SED shape and the relationship between envelope mass and bolometric luminosity can be extended to the study of high-mass star formation. The 8-1200μm SED of YSOs in 42 regions of massive star formation has been reconstructed using MSX, IRAS, and submm data partly available from previous works. Apart form IRAS catalogue fluxes, the fluxes in the Mid-IR and sub-mm/mm were derived directly from the images. The SEDs were fitted to an extensive grid of envelope models with embedded ZAMS stars, available from the literature. Sources which could not be fitted with a single model were then fitted with a two-component model composed by an embedded ZAMS for the mid-IR part and a single-temperature optically thin greybody for the longer wavelength emitting component. Sources were classified as "IR" if they were fitted with an embedded ZAMS envelope, and "MM" if they could only be fitted with a greybody with a peak at high λ; further subclassification was based on being the most massive object in the field ("P", for primary) or not ("S", for secondary). The different classes of sources identified in our analysis have very different SEDs and occupy distinct areas in the L_{bol}-M_{env} diagram; by analogy with the low-mass regime, we see that MM-P, IR-P and IR-S objects could be interpreted as the high-mass analogue of Class 0-I-II. Simple toy-model evolutionary tracks based on the turbulent core prescriptions show that the three classes of sources possibly mark different periods in the formation of a massive YSO. The IR-P objects are consistent with being at the end of the main accretion phase, while MM-P sources are probably in an earlier evolutionary stage. The timescales for the formation decrease from $\sim 4\,10^5$ to $\sim 1\,10^5$ years with stellar mass increasing form ~ 6 to $\sim 40 M_\odot$; these timescales, and the association with young clusters with median stellar age of a few 10^6 years suggest that the most massive objects are among the last ones to form. Our results are consistent with the high-mass star formation being a scaled-up analogue of the traditional accretion-dominated paradigm valid for the low-mass regime.

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ftp://ftp.sic.rm.cnr.it/incoming/ifsi.rm.cnr.it/Sergio.Molinari/Public

Sequestration of Noble Gases by in Protoplanetary Disks and Outer Solar System Composition

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We study the efficiency of the noble gas sequestration by the ion H_3^+ in the form of XH_3^+ complexes (with X = argon, krypton, or xenon) in gas-phase conditions similar to those encountered during the cooling of protoplanetary disks. We show that complexes form very stable structures in the gas phase and that their binding energies are much higher than those involved in the structures of X-H_2O hydrates or pure X-X condensates. This implies that in the presence of H_3^+ ions, argon, krypton, or xenon are likely to remain sequestrated in the form of complexes embedded in the gas phase rather than forming ices during the cooling of protoplanetary disks. The amount of the deficiency depends on how much H_3^+ is available and efficient in capturing noble gases. In the dense gas of the mid-plane of solar nebula H_3^+ is formed by the ionization of H_2 from energetic particles such as those in cosmic rays or those ejected by the young Sun. Even using the largest estimate of the cosmic-ray ionization rate, we compute that the abundance is 2 and 3 orders of magnitude lower than the xenon and krypton abundance, respectively. Estimating the ionization induced by the young Sun, on the other hand, is very uncertain but leaves the possibility of having enough to make krypton and xenon trapping efficient. This may cause a deficiency of Kr, Xe, and to a lower extent of Ar, in the forming icy planetesimals. We then suggest that this sequestration mechanism may explain the deficiency of Titan in noble gases revealed by the Huygens probe measurements. Similarly, comets formed from crystalline water ice in the outer nebula should be also deficient in krypton and xenon, and to a lower extent in argon, in agreement with some recent observations.

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The Nature of the Dense Core Population in the Pipe Nebula: Core and Cloud Kinematics from $C^{18}O$ Observations

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We present molecular line observations of 94 dark cloud cores identified in the Pipe nebula through near-IR extinction mapping. Using the Arizona Radio Observatory 12 m telescope, we obtained spectra of these cores in the J = 1-0 transition of $C^{18}O$. We used the measured core parameters, $T_R^\star$, Δv, v_{lsr}, radius, and mass, to explore the internal kinematics of the cores, as well as their radial motions through the larger molecular cloud. We find that the vast majority of the dark extinction cores are true cloud cores, rather than the superposition of unrelated filaments. While we identify no significant correlations between the cores' internal gas motions and their other physical parameters, we identify spatially correlated radial velocity variations that outline two main kinematic components of the cloud. The largest is a 15 pc long filament that is surprisingly narrow both in spatial dimensions and in radial velocity. Beginning in the "Stem" of the Pipe, this filament displays uniformly small $C^{18}O$ line widths ($\Delta v \sim 0.4$ km s^1), as well as core-to-core motions only slightly in excess of the gas sound speed. The second component outlines what appears to be part of a large (2 pc; 10^3 $M_\odot$) ringlike structure. Cores associated with this component display both larger line widths and core-to-core motions than cores in the main cloud. The Pipe molecular ring may represent a primordial structure related to the formation of this cloud.

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SCUBA and Spitzer observations of the Taurus molecular cloud – pulling the bull's tail

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We present continuum data from the Submillimetre Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT), and the Mid-Infrared Photometer for Spitzer (MIPS) on the Spitzer Space Telescope, at submillimetre and infrared wavelengths respectively. We study the Taurus molecular cloud 1 (TMC1), and in particular the region of the Taurus Molecular Ring (TMR). In the continuum data we see no real evidence for a ring, but rather we see one side of it only, appearing as a filament. We name the filament 'the bull's tail'. The filament is seen in emission at 850, 450 and 160 μm, and in absorption at 70 μm. We compare the data with archive data from the Infra-Red Astronomical Satellite (IRAS) at 12, 25, 60, 100 μm, in which the filament is also seen in absorption. We find that the emission from the filament consists of two components: a narrow, cold ($\sim$8 K), central core; and a broader, slightly warmer ($\sim$12 K), shoulder of emission. We use a radiative transfer code to model the filament's appearance, either in emission or absorption, simultaneously at each of the different wavelengths. Our best fit model uses a Plummer-like density profile and a homogeneous interstellar dust grain population. Unlike previous work on a similar, but different filament in Taurus, we require no grain coagulation to explain our data.

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Population III Star Formation in a ΛCDM Universe. II. Effects of a Photodissociating Background

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We examine aspects of primordial star formation in the presence of a molecular hydrogen-dissociating ultraviolet background. We compare a set of AMR hydrodynamic cosmological simulations using a single cosmological realization, but with a range of ultraviolet background strengths in the Lyman-Werner band. This allows us to study the effects of Lyman-Werner radiation on suppressing H_2 cooling at low densities, as well as the highdensity evolution of the collapsing cloud core in a self-consistent cosmological framework. We find that the addition of a photodissociating background results in a delay of the collapse of high-density gas at the center of the most massive halo in the simulation and, as a result, an increase in the virial mass of this halo at the onset of baryon collapse. We find that, contrary to previous results, Population III star formation is not suppressed for $J_{21} \geq 0.1$, but occurs even with backgrounds as high as $J_{21} = 1$. We find that H_2 cooling leads to collapse despite the depressed core molecular hydrogen fractions due to the elevated H_2 cooling rates at $T = 2 - 5 \times 10^3$K. We observe a relationship between the strength of the photodissociating background and the rate of accretion onto the evolving protostellar cloud core, with higher LW background fluxes resulting in higher accretion rates. Finally, we find that the collapsing cloud cores in our simulations do not fragment at densities below $n \sim 10^{10}$ cm^3, regardless of the strength of the LW background, suggesting that Population III stars forming in halos with $T_{vir} \sim 10^4$ K may still form in isolation.

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Growing and moving low-mass planets in non-isothermal disks

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Aims. We study the interaction of a low-mass planet with a protoplanetary disk with a realistic treatment of the energy balance by doing radiation-hydrodynamical simulations. We look at accretion and migration rates and compare them to isothermal studies.
Methods. We used a three-dimensional version of the hydrodynamical method RODEO, together with radiative transport in the flux-limited diffusion approach.
Results. The accretion rate, as well as the torque on the planet, depend critically on the ability of the disk to cool efficiently. For densities appropriate to 5 AU in the solar nebula, the accretion rate drops by more than an order of magnitude compared to isothermal models, while at the same time the torque on the planet is positive, indicating outward migration. It is necessary to lower the density by a factor of 2 to recover inward migration and more than 2 orders of magnitude to recover the usual type I migration. The torque appears to be proportional to the radial entropy gradient in the unperturbed disk. These findings are critical for the survival of protoplanets, and they should ultimately find their way into population synthesis models.

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Hall magnetohydrodynamics of partially ionized plasmas

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The Hall effect arises in a plasma when electrons are able to drift with the magnetic field but ions cannot. In a fully-ionized plasma this occurs for frequencies between the ion and electron cyclotron frequencies because of the larger ion inertia. Typically this frequency range lies well above the frequencies of interest (such as the dynamical frequency of the system under consideration) and can be ignored. In a weakly-ionized medium, however, the Hall effect arises through a different mechanism – neutral collisions preferentially decouple ions from the magnetic field. This typically occurs at much lower frequencies and the Hall effect may play an important role in the dynamics of weakly-ionised systems such as the Earth's ionosphere and protoplanetary discs. To clarify the relationship between these mechanisms we develop an approximate single-fluid description of a partially ionized plasma that becomes exact in the fully-ionized and weakly-ionized limits. Our treatment includes the effects of ohmic, ambipolar, and Hall diffusion. We show that the Hall effect is relevant to the dynamics of a partially ionized medium when the dynamical frequency exceeds the ratio of ion to bulk mass density times the ion-cyclotron frequency, i.e. the Hall frequency. The corresponding length scale is inversely proportional to the ion to bulk mass density ratio as well as to the ion-Hall beta parameter. In a weakly ionized medium, the critical frequency becomes small enough that Hall MHD is an accurate representation of the dynamics. More generally, ohmic and ambipolar diffusion may also be important. We show that both ambipolar and Hall diffusion depend upon the fractional ionization of the medium. However, unlike ambipolar diffusion, Hall diffusion may also be important in the high fractional ionization limit. The wave properties of a partially-ionized medium are investigated in the ambipolar and Hall limits. We show that in the ambipolar regime wave damping is dependent on both fractional ionization and ion-neutral collision frequencies. In the Hall regime, since the frequency of a whistler wave is inversely proportional to the fractional ionization, and bounded by the ion-neutral collision frequency it will play an important role in the Earth's ionosphere, solar photosphere and astrophysical discs.

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Optical Interferometric Observations of Theta 1 Orionis C from NPOI and Implications for the System Orbit

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With the Navy Prototype Optical Interferometer (NPOI), the binary system θ^1 Orionis C, the most massive member of the Trapezium, was spatially resolved over a time period extending from February 2006 to March 2007. The data show significant orbital motion over the 14 months, and, after combining the NPOI data with previous measurements of the system from the literature, the observations span 10 years of the orbit. Our results indicate that the secondary did not experience an unusually close periastron passage this year, in contradiction to the prediction of a recently published, highly eccentric ∼11 year orbit. Future observations of this source will be required to improve the orbital solution. Possible implications of the results in terms of system distance are discussed, although a main conclusion of this work is that a definitive orbit solution will require more time to obtain sufficient phase coverage, and that the interaction effects expected at periastron did not occur in 2007.

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Seismic evolution of low/intermediate mass PMS stars

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This article presents a study of the evolution of the internal structure and seismic properties expected for low/intermediate mass Pre-Main Sequence (PMS) stars. Seismic and non-seismic properties of PMS stars were analysed. This was done using 0.8 to 4.4 $M_\odot$ stellar models at stages ranging from the end of the Hayashi track up to the Zero-Age Main-Sequence (ZAMS). This research concludes that, for intermediate-mass stars (M > 1.3 $M_\odot$), diagrams comparing the effective temperature ($T_{\rm eff}$) against the small separation can provide an alternative to Christensen-Dalsgaard (C-D) diagrams. The impact of the metal abundance of intermediate mass stars (2.5-4.4 $M_\odot$) has over their seismic properties is also evaluated.

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Infall and Outflow of Molecular Gas in Sgr B2

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Observations of two H_2CO ($3_{03} - 2_{02}$ and $3_{21} - 2_{20}$) lines and continuum emission at 1.3 mm towards Sgr B2(N) and Sgr B2(M) have been carried out with the SMA. The mosaic maps of Sgr B2(N) and Sgr B2(M) in both continuum and lines show a complex distribution of dust and molecular gas in both clumps and filaments surrounding the compact star formation cores. We have observed a decelerating outflow originated from the Sgr B2(M) core, showing that both the red-shifted and blue-shifted outflow components have a common terminal velocity. This terminal velocity is 58±2 km s^{-1}. It provides an excellent method in determination of the systematic velocity of the molecular cloud. The SMA observations have also shown that a large fraction of absorption against the two continuum cores is red-shifted with respect to the systematic velocities of Sgr B2(N) and Sgr B2(M), respectively, suggesting that the majority of the dense molecular gas is flowing into the two major cores where massive stars have been formed. We have solved the radiative transfer in a multi-level system with LVG approximation. The observed H_2CO line intensities and their ratios can be adequately fitted with this model for the most of the gas components. However, the line intensities between the higher energy level transition H_2CO ($3_{21} - 2_{20}$) and the lower energy level transition H_2CO ($3_{03} - 2_{02}$) is reversed in the red-shifted outflow region of Sgr B2(M), suggesting the presence of inversion in population between the ground levels in the two K ladders (K_{-1}= 0 and 2). The possibility of weak maser processes for the H_2CO emission in Sgr B2(M) is discussed.

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On the observability of resonant structures in planetesimal disks due to planetary migration

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The observed clumpy structures in debris disks are commonly interpreted as particles trapped in mean-motion resonances with an unseen exo-planet. Populating the resonances requires a migrating process of either the particles (spiraling inward due to drag forces) or the planet (moving outward). Because the drag time-scale in resolved debris disks is generally long compared to the collisional time-scale, the planet migration scenario might be more likely, but this model has so far only been investigated for planets on circular orbits. We present a thorough study of the impact of a migrating planet on a planetesimal disk, by exploring a broad range of masses and eccentricities for the planet. We discuss the sensitivity of the structures generated in debris disks to the basic planet parameters. We perform many N-body numerical simulations, using the symplectic integrator SWIFT, taking into account the gravitational influence of the star and the planet on massless test particles. A constant migration rate is assumed for the planet. The effect of planetary migration on the trapping of particles in mean motion resonances is found to be very sensitive to the initial eccentricity of the planet and of the planetesimals. A planetary eccentricity as low as 0.05 is enough to smear out all the resonant structures, except for the most massive planets. The planetesimals also initially have to be on orbits with a mean eccentricity of less than than 0.1 in order to keep the resonant clumps visible. This numerical work extends previous analytical studies and provides a collection of disk images that may help in interpreting the observations of structures in debris disks. Overall, it shows that stringent conditions must be fulfilled to obtain observable resonant structures in debris disks. Theoretical models of the origin of planetary migration will therefore have to explain how planetary systems remain in a suitable configuration to reproduce the observed structures.

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Unstable Disk Accretion onto Magnetized Stars: First Global Three-dimensional Magnetohydrodynamic Simulations

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We report on the first global threedimensional (3D) MHD simulations of disk accretion onto a rotating magnetized star through the Rayleigh-Taylor instability. The star has a dipole field misaligned relative to the rotation axis by a small angle θ. Simulations show that, depending on the accretion rate, a star may be in the stable or unstable regime of accretion. In the unstable regime, matter penetrates deep into the magnetosphere through several elongated "tongues" which deposit matter at random places on the surface of the star, leading to stochastic light curves. In the stable regime, matter accretes in ordered funnel streams and the light curves are almost periodic. A star may switch between these two regimes depending on the accretion rate and may thus show alternate episodes of ordered pulsations and stochastic light curves. In the intermediate regime, both stochastic and ordered pulsations are observed. For $\theta > 30°$, the instability is suppressed and stable accretion through funnel streams dominates.

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Galactic Edge Clouds. I. Molecular Line Observations and Chemical Modeling of Edge Cloud 2

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Edge Cloud 2 (EC2) is a molecular cloud, about 35 pc in size, with one of the largest galactocentric distances known to exist in the Milky Way. We present observations of a peak CO emission region in the cloud and use these to determine its physical characteristics. We calculate a gas temperature of 20 K and a density of $n(H_2) \sim 10^4$ cm^3. Based on our CO maps, we estimate the mass of EC2 at around 10^4 $M_\odot$ and continuum observations suggest a dust-to-gas mass ratio as low as 0.001. Chemical models have been developed to reproduce the abundances in EC2, and they indicate that heavy element abundances may be reduced by a factor of 5 relative to the solar neighborhood (similar to dwarf irregular galaxies and damped Lyα systems), very low extinction ($A_V < 4$ mag) due to a very low dusttogas mass ratio, an enhanced cosmicray ionization rate, and a higher UV field compared to local interstellar values. The reduced abundances may be attributed to the low level of star formation in this region and are probably also related to the continuing infall of primordial (or lowmetallicity) halo gas since the Milky Way formed. Finally, we note that shocks from the old supernova remnant GSH 1380194 may have determined the morphology and dynamics of EC2.

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Tentative Detection of C_4H toward the Low-Mass Protostar IRAS 04368+2557 in L1527

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The millimeter-wave rotational emission line (J = 9-8) of the negative ion, C_4H, has tentatively been detected toward the low-mass Class 0 protostar IRAS 04368+2557 in L1527 with the IRAM 30 m telescope. The column density of C_4H is determined to be 1.1×10^{10} cm^{-2}. The [C_4H]/[C_4H] ratio is found to be 6.8×10^{-5}, which is much lower than the [C_6H]/[C_6H] ratio (0.093). From this result, the rate coefficient for the radiative attachment reaction between C_4H and electron is estimated to be as small as 3×10^{-11} cm^{3}s^{-1} on the basis of the simplified chemical model. The present observation has demonstrated the uniqueness and importance of L1527 in searching for a new carbon-chain molecule in a star-forming region.

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Abundant Carbon-Chain Molecules toward the Low-Mass Protostar IRAS 04368+2557 in L1527

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We have detected the high-excitation lines of carbon-chain molecules such as C_4H_2 (J = $10_{0,10} - 9_{0,9}$), C_4H ($N = 9-8$, F1, F2), lC_3H_2 ($4_{1,3}3_{1,2}$), and CH_3CCH (J = $5-4$, $k = 2$) toward a low-mass star-forming region, L1527. In particular, the F1 line of C_4H is as strong as 1.7 K (T_{MB}). The rotational temperature of C_4H_2 is determined to be 12.3 ± 0.8 K, which is higher than that in TMC1 (3.8 K). Furthermore, the column density of C_4H_2 is derived to be about 1/4 of that in TMC1, indicating that carbon-chain molecules are abundant in L1527 for a star-forming region. Small mapping observations show that the C_4H, C_4H_2, and c-C3H2 emissions are distributed from the infalling envelope to the inner part. Furthermore, we have detected the lines of C_5H, HC_7N, and HC_9N in the 20 GHz region. Since the carbon-chain molecules are generally deficient in star-forming cores, the above results cannot simply be explained by the existing chemical models. The following hypothesis is proposed. If the timescale of the prestellar collapse in L1527 were shorter than those of the other star-forming cores, the carbon-chain molecules could survive in the central part of the core. In addition, regeneration processes of the carbon-chain molecules due to star formation activities would play an important role. Evaporation of CH_4 from the grain mantles would drive the regeneration processes.

The present observations show new chemistry in a warm and dense region near the protostars, which is named “warm carbon-chain chemistry (WCCC).”

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Chemical abundances in six nearby star-forming regions: implications for galactic evolution and planet searches around very young stars

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In this paper we present a study of chemical abundances in six star-forming regions. Stellar parameters and metallicities are derived using high-resolution, high S/N spectra of weak-line T-Tauri stars in each region. The results show that nearby starforming regions have a very small abundance dispersion (only 0.033 dex in [Fe/H]). The average metallicity found is slightly below that of the Sun, although compatible with solar once the errors are taken into account. The derived abundances for Si and Ni show that the observed stars have the abundances typical of Galactic thin disk stars of the same metallicity. The impact of these observations is briefly discussed in the context of the Galactic chemical evolution, local inter-stellar medium abundances, and in the origin of metal-rich stars in the solar neighbourhood (namely, stars more likely to harbour planets). The implication for future planet-search programmes around very young, nearby stars is also discussed.

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TMC-1C: An Accreting Starless Core

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We have mapped the starless core TMC-1C in a variety of molecular lines with the IRAM 30 m telescope. High-density tracers show clear signs of self-absorption, and subsonic infall asymmetries are present in $N_2H^+(10)$ and $DCO^+(21)$ lines. The inward velocity profile in $N_2H^+(10)$ is extended over a region about 7000 AU in radius around the dust continuum peak, which is the most extended “infalling” region observed in a starless core with this tracer. The kinetic temperature ($\sim$ 12 K) measured from $C^{17}O$ and $C^{18}O$ suggests that their emission comes from a shell outside the colder interior traced by the millimeter continuum dust. The $C^{18}O(21)$ excitation temperature drops from 12 to $\simeq$10 K away from the center. This is consistent with a volume density drop of the gas traced by the $C^{18}O$ lines, from $\simeq 4 \times 10^4$ cm^3 toward the dust peak to $\simeq 6 \times 10^3$ cm^3 at a projected distance from the dust peak of 80$''$ (or 11,000 AU). The column density implied by the gas and dust show similar N_2H^+ and CO depletion factors ($f_D \leq 6$). This can be explained with a simple scenario in which: (1) the TMC-1C core is embedded in a relatively dense environment [$n(H_2) \simeq 10^4$ cm^3], where CO is mostly in the gas phase and the N_2H^+ abundance had time to reach equilibrium values; (2) the surrounding material (rich in CO and N_2H^+) is accreting onto the dense core nucleus; (3) TMC-1C is older than 3×10^5 yr, to account for the observed abundance of N_2H^+ across the core ($\simeq 10^{10}$ with respect to H_2);

and (4) the core nucleus is either much younger ($\simeq 10^4$ yr) or "undepleted" material from the surrounding envelope has fallen toward it in the past 10,000 yr.

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Applicability of colour index calibrations to T Tauri stars

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We examine the applicability of effective temperature scales of several broad band colours to T Tauri stars (TTS). We take into account different colour systems as well as stellar parameters like metallicity and surface gravity which influence the conversion from colour indices or spectral type to effective temperature. For a large sample of TTS, we derive temperatures from broad band colour indices and check if they are consistent in a statistical sense with temperatures inferred from spectral types. There are some scales (for $V-H$, $V-K$, $I-J$, $J-H$, and $J-K$) which indeed predict the same temperatures as the spectral types and therefore can be at least used to confirm effective temperatures. Furthermore, we examine whether TTS with dynamically derived masses can be used for a test of evolutionary models and effective temperature calibrations. We compare the observed parameters of the eclipsing T Tauri binary V1642 Ori A to the predictions of evolutionary models in both the H-R and the Kiel diagram using temperatures derived with several colour index scales. We check whether the evolutionary models and the colour index scales are consistent with coevality and the dynamical masses of the binary components. It turns out that the Kiel diagram offers a stricter test than the H-R diagram. Only the evolutionary models of Baraffe et al. (1998) with mixing length parameter $\alpha = 1.9$ and of D'Antona & Mazzitelli (1994, 1997) show consistent results in the Kiel diagram in combination with some conversion scales of Houdashelt et al. (2000) and of Kenyon & Hartmann (1995).

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Chemical and Thermal Structure of Protoplanetary Disks as Observed with ALMA

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We predict how protoplanetary disks around lowmass young stars would appear in molecular lines observed with the ALMA interferometer. Our goal is to identify those molecules and transitions that can be used to probe and distinguish between chemical and physical disk structure and to define necessary requirements for ALMA observations. Disk models with and without vertical temperature gradient as well as with uniform abundances and those from a chemical network are considered. As an example, we show the channel maps of HCO_+(43) synthesized with a non-LTE line radiative transfer code and used as an input to the GILDAS ALMA simulator to produce noiseadded realistic images. The channel maps reveal complex asymmetric patterns even for the model with uniform abundances and no vertical thermal gradient. We find that a spatial resolution of 0.2″-0.5″ and 0.5-10 hr of integration time will be needed to disentangle largescale temperature gradients and the chemical stratification in disks in lines of abundant molecules.

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A young massive planet in a stardisk system

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There is a general consensus that planets form within disks of dust and gas around newly born stars. Details of their

formation process, however, are still a matter of ongoing debate. The timescale of planet formation remains unclear, so the detection of planets around young stars with protoplanetary disks is potentially of great interest. Hitherto, no such planet has been found. Here we report the detection of a planet of mass $(9.8 \pm 3.3)\mathrm{M}_{Jupiter}$ around TW Hydrae (TW Hya), a nearby young star with an age of only 810 Myr that is surrounded by a well-studied circumstellar disk. It orbits the star with a period of 3.56 days at 0.04 au, inside the inner rim of the disk. This demonstrates that planets can form within 10 Myr, before the disk has been dissipated by stellar winds and radiation.

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Can giant planets form by gravitational fragmentation of discs?

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Context: Gravitational fragmentation has been proposed as a mechanism for the formation of giant planets in close orbits around solar-type stars. However, it is debatable whether this mechanism can function in the inner regions ($R \lesssim 40$ AU) of real discs.
Aims: We investigate the thermodynamics of the inner regions of discs and their propensity to fragment.
Methods: We use a newly developed method for treating the energy equation and the equation of state, which accounts for radiative transfer effects in SPH simulations of circumstellar discs. The different chemical and internal states of hydrogen and the properties of dust at different densities and temperatures (ice coated dust grains at low temperatures, ice melting, dust sublimation) are all taken into account by the new method.
Results: We present radiative hydrodynamic simulations of the inner regions of massive circumstellar discs and examine two cases: (i) a disc irradiated by a cool background radiation field ($T_{\rm BGR} \sim 10\,{\rm K}$) and (ii) a disc heated by radiation from its central star ($T_{\rm BGR} \sim 1200{\rm K}[R/{\rm AU}]^{-1}$). In neither case does the disc fragment: in the former because it cannot cool fast enough and in the latter because it is not gravitationally unstable. Our results (a) corroborate previous numerical results using different treatments for the hydrodynamics and the radiative transfer, and (b) confirm our own earlier analytic predictions.
Conclusion: Disc fragmentation is unlikely to be able to produce giant planets around solar-type stars at radii $\lesssim 40$ AU.

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http://www.astro.cf.ac.uk/pub/Dimitrios.Stamatellos/publications/

Disc evolution and the relationship between $L_{\rm acc}$ and L_* in T Tauri stars

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We investigate the evolution of accretion luminosity $L_{\rm acc}$ and stellar luminosity L_* in pre-mainsequence stars. We make the assumption that when the star appears as a Class II object, the major phase of accretion is long past, and the accretion disc has entered its asymptotic phase. We use an approximate stellar evolution scheme for accreting pre-mainsequence stars based on Hartmann, Cassen & Kenyon, 1997. We show that the observed range of values $k = L_{\rm acc}/L_*$ between 0.01 and 1 can be reproduced if the values of the disc mass fraction $M_{\rm disc}/M_*$ at the start of the T Tauri phase lie in the range $0.01 - 0.2$, independent of stellar mass. We also show that the observed upper bound of $L_{\rm acc} \sim L_*$ is a generic feature of such disc accretion. We conclude that as long as the data uniformly fills the region between this upper bound and observational detection thresholds, then the degeneracies between age, mass and accretion history severely limit the use of this data for constraining possible scalings between disc properties and stellar mass.

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Dense Molecular Gas in a Young Cluster around MWC 1080: Rule of the Massive Star

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We present CS J = 2 → 1, ^{13}CO J = 1 → 0, and C^{18}O J = 1 → 0, observations with the 10 element Berkeley Illinois Maryland Association (BIMA) array toward the young cluster around the Be star MWC 1080. These observations reveal a biconical outflow cavity with size ∼0.3 and 0.05 pc for the semimajor and semiminor axis and ∼ 45° position angle. These transitions trace the dense gas, which is likely the swept-up gas of the outflow cavity, rather than the remaining natal gas or the outflow gas. The gas is clumpy; 32 clumps are identified. The identified clumps are approximately gravitationally bound and consistent with a standard isothermal sphere density, which suggests that they are likely collapsing protostellar cores. The gas kinematics suggests that velocity gradients exist that imply effects from the inclination of the cavity and MWC 1080. The kinematics of dense gas has also been affected by either outflows or stellar winds from MWC 1080, and lower mass clumps are possibly under stronger effects from MWC 1080 than higher mass clumps. In addition, low-mass cluster members tend to be formed in the denser and more turbulent cores, compared to isolated low-mass star-forming cores. This results from the contributions of nearby forming massive stars, such as outflows or stellar winds. Therefore, we conclude that in clusters like the MWC 1080 system, effects from massive stars dominate the star-forming environment in both the kinematics and dynamics of the natal cloud and the formation of low-mass cluster members. This study provides insights into the effects of MWC 1080 on its natal cloud, and suggests a different low-mass star-forming environment in clusters compared to isolated star formation.

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Thermal Waves in Irradiated Protoplanetary Disks

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Protoplanetary disks are mainly heated by radiation from the central star. Since the incident stellar flux at any radius is sensitive to the disk structure near that location, destabilizing feedback may be present. Previous investigations have shown that the disk will be stable to finite-amplitude temperature perturbations if the vertical height of the optical surface is everywhere directly proportional to the gas scale height and if the intercepted fraction of stellar radiation is determined from the local grazing angle. We show that these assumptions may not be generally applicable. Instead, we calculate the quasi-static thermal evolution of irradiated disks by directly integrating the global optical depth to determine the optical surface and the total emitting area filling factor of surface dust. We show that in disks with modest mass accretion rates, thermal waves are spontaneously and continually excited in the outer disk, propagate inward through the planet-forming domains, and dissipate at small radii where viscous dissipation is dominant. This state is quasi-periodic over several thermal timescales, and its pattern does not depend on the details of the opacity law. The viscous dissipation resulting from higher mass accretion stabilizes this instability such that an approximately steady state is realized throughout the disk. In passive protostellar disks, especially transitional disks, these waves induce significant episodic changes in spectral energy distributions, on timescales of years to decades, because the midplane temperatures can vary by a factor of 2 between the exposed and shadowed regions. The transitory peaks and troughs in the potential vorticity distribution may also lead to baroclinic instability and excite turbulence in the planet-forming regions.

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Submillimeter Structure of the Disk of the Butterfly Star

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We present a spatially resolved 894 μm map of the circumstellar disk of the Butterfly star in Taurus (IRAS 04302+2247), obtained with the Submillimeter Array (SMA). The predicted and observed radial brightness profile agree well in the outer disk region, but differ in the inner region with an outer radius of $\sim$80-120 AU. In particular, we find a local minimum of the radial brightness distribution at the center, which can be explained by an increasing density / optical depth combined with the decreasing vertical extent of the disk towards the center. Our finding indicates that young circumstellar disks can be optically thick at wavelengths as long as 894 μm. While earlier modeling lead to general conclusions about the global disk structure and, most importantly, evidence for grain growth in the disk (Wolf, Padgett, & Stapelfeldt 2003), the presented SMA observations provide more detailed constraints for the disk structure and dust grain properties in the inner, potentially planet-forming region (inside $\sim$80-120 AU) vs. the outer disk region ($\sim$120-300 AU).

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The Interaction between a Pulsed Astrophysical Jet and Small-Scale Heterogeneous Media

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We have performed two-dimensional hydrodynamic simulations of a pulsed astrophysical jet propagating through a medium that is populated with circular inhomogeneities, or “clumps”, which are smaller than the jet width. The clumps are seen to affect the jet in several ways, such as impeding jet propagation and deflecting the jet off-axis. While there has been some debate as to the prevalence of these types of condensations in the ISM or in molecular clouds, the exploration of this region of parameter space nonetheless both shows the potential for these clumps to disrupt astrophysical jets and yields results which recover aspects of recent observations of Herbig-Haro objects. We find that the propagation of the jet and the vorticity induced in the clump/ambient medium correlate well with a “dynamic filling function” across all the simulations.

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New constraints on the membership of the T dwarf S Ori 70 in the σ Orionis cluster

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Aims. The nature of S Ori 70 (S Ori J053810.1-023626), a faint mid-T type object found towards the direction of the young σ Orionis cluster, is still under debate. We intend to find out whether it is a field brown dwarf or a 3-Myr old planetary-mass member of the cluster.
Methods. We report on near-infrared JHK_s and mid-infrared [3.6] and [4.5] IRAC/Spitzer photometry recently obtained for S Ori 70. The new near-infrared images (taken 3.82 yr after the discovery data) allowed us to derive the first proper motion measurement for this object.
Results. The colors $(H - K_s)$, $(J - K_s)$ and K_s - [3.6] appear discrepant when compared to T4-T7 dwarfs in the field. This behavior could be ascribed either to a low-gravity atmosphere or to an atmosphere with a metallicity that is significantly different than solar. The small proper motion of S Ori 70 (11.0 ± 5.9 mas yr^{-1}) indicates that this object is farther away than expected if it were a single field T dwarf lying in the foreground of the σ Orionis cluster. Our measurement is consistent with the proper motion of the cluster within 1.5σ the astrometric uncertainty.
Conclusions. Taking into account both S Ori 70's proper motion and the new near- and mid-infrared colors, a low-gravity atmosphere remains as the most likely explanation for our observations. This supports S Ori 70's membership in σ Orionis, with an estimated mass in the interval 2-7 $M_{\rm Jup}$, in agreement with our previous derivation.

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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).

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Observational Constraints on Circumstellar Disk Evolution and Terrestrial Planet Formation

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Ph.D degree awarded: January 2008

Studying circumstellar disk evolution and planet formation around other stars provides a context for the formation and the uniquness of the solar system and the Earth in particular. In this thesis, we investigate circumstellar disk evolution and terrestrial planet formation from a comprehensive, multiwavelength survey of the massive double cluster, h and χ Persei. Spitzer IRAC/MIPS observations of disks surrounding h and χ Per stars exhibit a stellar mass/spectral type-dependent frequency of warm circumstellar dust emission, consistent with the planet formation process running to completion faster (slower) for high (intermediate/low) mass stars. These stars also exhibit a wavelength-dependent frequency of circumstellar dust emission from K band through 24 μm, a result consistent with planet formation running to completion fastest from the inside out. Spectroscopy is used to constrain the stellar population of the Double Cluster, specifically χ Persei and to identify accreting sources. We derive an extinction of E(B-V) $\sim$ 0.56, a distance modulus of 11.85, and an age of 14 Myr $\pm$ 1.5 Myr for χ Persei, in agreement with previous, more shallow surveys. We find evidence for a low-density halo population of sources surrounding both h and χ Persei that is about as populous as the core regions and may have a slightly larger, $\sim$ 5 Myr age spread. Detailed modeling of IRAC-excess sources reveals that many, if not most, of them are not optically-thick primordial disks or transitions disks but warm (250-400 K) debris disks, indicative of terrestrial planet formation. *The majority of known stars with ongoing terrestrial planet formation are now found from this survey.* Many sources also have much colder dust populations (50-200 K), revealing evidence for planet formation at larger stellocentric distances and a wide range of dust clearing in disks. Finally, we compare results for h and χ Persei with that for other 5 Myr - 1 Gyr clusters with debris disks to provide a picture of the evolution of debris emission from planet formation. The 24 μm excess from debris disks 'rises' from 5 to 10 Myr, peaks from 10 - 20 Myr and 'falls' from 20 Myr onwards. Future observations, especially from Spitzer and JWST, will provide a thorough study of planet formation in the most massive evolved open cluster within 2.5 kpc of the Sun.

http://www.cfa.harvard.edu/∼tcurrie/thesis.pdf

Hydrodynamical Simulations of Jets from Young Stars and Proper Motions of Herbig-Haro Objects

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PhD. degree awarded: January 2008

In recent years techniques which are used to explore Herbig Haro (HH) objects have advanced substantially. Through large telescopes as those in Hawaii, Chile and the Hubble Space Telescope, it has become possible to observe these objects with subarsecond angular resolution. Also, with the development of computers and hydrodynamical codes it has become possible to calculate numerical models of HH objects in 3D, with higher resolutions than ever before.

In my doctoral research I study HH objects through simulations carried out with the Yguazú numerical code and with observations made with the NTT, Subaru Telescope and HST. I study the interaction of jets, emitted by young stars, with their surroundings and themselves. The theoretical part of my work consists of three chapters in which the following subjects are investigated:

- Spectra emitted by the internal working surfaces located along the jets that are ejected by young stars and characterized by a variable ejection velocity. Predictions for emission line coefficients for a set of emission lines have been calculated.
- Interaction of the Herbig Haro object HH 555 with the ionizing photon flux and the ionized interstellar wind or the expanding H II region. The importance of the photon flux on the shape and visibility the HH jet is explored.
- Behavior of the numerical solution for an internal working surface as a function of the resolution of the simulation.

The second part of the thesis consists of studies based in observations. Here, the following subjects are studied:

- Proper motions of the HH flows around the head of the cometary globule CG 30. This study is based on two sets of optical emission line images made with the NTT and Subaru Telescope in the years 1995 and 2006. Various new HH flows have been discovered and are related to the stellar sources previously detected at submillimeter wavelengths.
- Proper motions of the system of two HH jets: HH 110 and HH 270. For this study two sets of images obtained with the NTT and Subaru Telescope in the years 1991 and 2006 have been used. Also, proper motions of HH 110 from two HST images obtained in the years 2005 and 2006, are calculated. The high resolution of these images allowed me to study the level of turbulence in HH 110.

Post-doctoral position on star formation at LAOG, Grenoble

A 2-year postdoctoral position is available at the Laboratoire d'Astrophysique de l'Observatoire de Grenoble (LAOG, http://www-laog.obs.ujf-grenoble.fr) in the framework of the European Commission FP6 Marie Curie Research Training Network "CONSTELLATION: The origin of stellar masses" (http://www.constellation-rtn.eu).

The successful candidate will take a significant role in a large-scale observing program aimed at searching for the origin of brown dwarfs, their physical properties, and their relationship to planets. He/she will be involved in the photometric analysis and spectroscopic follow up of an on-going Large Program at CFHT which uses the wide-field infrared camera WIRCAM to search for the lowest-mass objects in nearby star-forming regions.

The appointment is for 2 years, starting as early as summer 2008, but no later than November 30 2008. Candidates with expertise in infrared imaging and spectroscopy are encouraged to apply. Additional expertise in N-body simulations of low-mass populations in stellar clusters is also welcome.

Application forms, eligibility criteria, and terms of employment are to be found at:

http://www.constellation-rtn.eu/wiki/index.php/PhD_and_Postdoctoral_Positions_Available

The closing date for applications is March 1st, 2008.

PhD Position in Theoretical Star Formation

A PhD position is available at the University of Western Ontario, to work in the group of Dr. Shantanu Basu, on theory/simulations of star formation. The position is for 3 years if a Masters degree is already complete, and for 5 years if starting immediately after the Bachelor's degree. The position begins in Fall 2008. The project involves performing three-dimensional simulations of cloud fragmentation or core collapse including the effects of turbulence and magnetic fields under conditions of non-ideal MHD. More information on ongoing research in the group may be obtained at http://www.astro.uwo.ca/∼basu/. To initiate the application process, please send a CV and cover letter stating research interests to Shantanu Basu at the address below. Email contact is most efficient and preferred.

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e-mail: basu *at* astro.uwo.ca

Consideration of applicants will continue until May 2008.

Postdoctoral fellowship on "Near-infrared interferometric studies of young stars"

INAF Istituto Nazionale di Astrofisica
OSSERVATORIO ASTROFISICO DI ARCETRI
Largo Fermi 5, 50125 Firenze, Italy

International Post-Doctoral Fellowship

A post-doctoral fellowship is available at the Arcetri Astrophysical Observatory (INAF). The fellowship intends to support the activity of the Star Formation Group in exploiting the new interferometric capabilities offered by VLTI at ESO. Applicants should have research interests and experience in one or more of the following broad areas: star formation, disk evolution, planet formation.

The applicant should have demonstrated experience in acquiring, reducing and analyzing interferometric infrared data. The fellow is expected to use and exploit the Amber/GTO data available to Arcetri and will have the opportunity to collaborate with the members of the Star Formation Group according to her/his research interests. Informal enquiries may be addressed to Dr. Antonella Natta (email natta *at* arcetri.astro.it).

The duration of the fellowship is one year, renewable for a second year subject to funding availability and positive assessment of the research activity. The gross yearly salary is expected to be around 30000 (Cap. 1.05.08-CRAM 1.01.02.01). Starting of the appointment is foreseen in May-June 2008. All requirements for the PhD must be completed by January 2008.

Interested individuals should send a Curriculum Vitae, list of publications and statement of research interests only in electronic form (PDF format preferred) to Dr. Antonella Natta at the address: natta *at* arcetri.astro.it . They should also arrange to have three letters of reference sent directly to the same e-mail address. Applications and letters of reference received before 29 February 2008 will be given full consideration.

Reference address:

Dr. Antonella Natta
INAF- Osservatorio Astrofisico di Arcetri
Largo E. Fermi 5 - 50125 Firenze, Italy
phone: +39 055-2752239
fax: +39 055-220039
E-mail: natta *at* arcetri.astro.it

http://www.arcetri.astro.it/cgi-bin/wb.py?posti

PhD positions: Water in Star-forming Regions

Two 4-year PhD positions are available to study the physical and chemical evolution of low-mass star-forming regions using data on water and related molecules to be obtained in the context of two approved Herschel key programs, WISH and DIGIT. Complementary ground-based submillimeter programs using JCMT, APEX and submillimeter interferometers are planned as well. The analysis will involve state-of-the-art radiative transfer techniques and chemical-dynamical models.

One PhD position will be located at Leiden Observatory, The Netherlands, working mostly with Herschel-HIFI data, whereas the second position will be at the Max-Planck Institut für Extraterrestrische Physik (MPE), Germany, working mostly with Herschel-PACS data. Both PhDs will be awarded at Leiden University.

Applications should include a curriculum vitae (with a list of grades for exams), a brief statement of research experience, and the names of at least two people who can serve as a reference. Selection of candidates will start on MARCH 1 2008 and will continue until the positions are filled. The positions are open to students of all nationalities with the equivalent of a "doctoraal" (Masters) degree in astronomy, physics or chemistry. The starting date for the positions can be anytime in 2008. Please send applications to:

Prof. dr. E.F. van Dishoeck,
Leiden Observatory,
P.O. Box 9513,
2300 RA Leiden,
The Netherlands.

FAX: +31-71-5275819;
e-mail submission: jobs *at* strw.leidenuniv.nl;
e-mail inquiries: ewine *at* strw.leidenuniv.nl

See http://www.strw.leidenuniv.nl/
http://www.strw.leidenuniv.nl/~ewine/
http://www.strw.leidenuniv.nl/WISH/
http://www.mpe.mpg.de/ir/
http://peggysue.as.utexas.edu/DIGIT/

for further information about Leiden Observatory, MPE and the Herschel key programs. The research is carried out in the framework of the Netherlands Research School for Astronomy (NOVA) and the International Max-Planck Research School on Astrophysics (IMPRS).

Planet Formation Processes and the Development of Prebiotic Conditions

March 18-21 2008

Pasadena, California, USA

The NASA Jet Propulsion Laboratory (JPL) Protoplanetary Disk Initiative is pleased to announce a workshop to be held on the Caltech campus in Pasadena, California, 18-21 March 2008. The workshop will be organised so that there will be presentations in the morning followed by discussions in small working groups in the afternoon, with the working groups reporting on their findings on the final morning.

The four working groups will be focused around the following topic areas:

I. The magneto-rotational instability in star and planet formation
II. Chemical processing of primordial material in protostellar disks
III. Dust evolution and planetesimal formation
IV. The signatures of planets in transitional and debris disks

Each working group will address a specific question related to their discipline:

I. Where does magnetic activity occur in disks?
II. What was the chemical environment during the formation of Jupiter and Saturn?
III. How can the gas drag catastrophe be avoided?
IV. How can we distinguish between different mechanisms for forming central holes in protostellar and transitional disks?

Due to the limited number of attendees that we will be able to host, the workshop will have a very specific focus, and a limited capacity. The registration fee will be dependent on the number of attendees, but will in all likelihood be small. **If you would like to be considered for this workshop, please contact Paul.M.Woods *at* jpl.nasa.gov by February 8th 2008.**

Confirmed attendees:

Y. Aikawa, R. Alexander, J. Blum, F. Brauer, G. Bryden, A. Carballido, J. Carr, C. Ceccarelli, S. Charnley, J. Cuzzi, S. Desch, C. Dominik, K. Dullemond, J. Eisner, P. Estrada, A. Glassgold, U. Gorti, K. Grogan, D. Hollenbach, A. Johansen, I. Kamp, H. Klahr, K. Kretke, D. Lin, A. Markwick-Kemper, D. Matson, F. Menard, J. Muzerolle, J. Najita, G. Orton, T. Owen, P. Padoan, C. Qi, A. Quillen, A. Roberge, S. Robinson, R. Salmeron, C. Salyk, T. Sano, K. Stapelfeldt, D. Stevenson, W. Traub, N. Turner, M. Velli, M. Wardle, S. Weidenschilling, K. Willacy, P. Woods, A. Youdin, A. Zsom.

Please address any further queries to:

Paul Woods (Paul.M.Woods *at* jpl.nasa.gov)
Augusto Carballido (Augusto *at* jpl.nasa.gov)
Geoff Bryden (Geoffrey.Bryden *at* jpl.nasa.gov)
Neal Turner (Neal.Turner *at* jpl.nasa.gov)
Marco Velli (Marco.C.Velli *at* jpl.nasa.gov)

The workshop website will soon be available at: http://diskworkshop.jpl.nasa.gov Sponsorship is provided by JPL's Center for Exoplanet Science.

Final Delivery of Data from the c2d Legacy Project: IRAC and MIPS

Neal J. Evans II[1], et al.

[1] The University of Texas at Austin, Department of Astronomy, 1 University Station C1400, Austin, Texas 78712–0259

E-mail contact: nje *at* astro.as.utexas.edu

This report documents the fourth and final delivery of IRAC and MIPS data by the c2d team. We are delivering mosaics and catalogs for 5 large clouds, 82 small cores, and 189 regions around weak-line T Tauri Stars. We include discussions of our data processing, the products themselves, and tests of completeness and reliability, as well as a brief section on how to use the catalogs. We also discuss the various artifacts that have been corrected and those that may remain in the data. A table lists all the column headers in our source catalogs and refers the readers to sections or tables with more information. We include several new products, including our full archive and catalogs of candidate young stellar objects. We also deliver catalogs from the SWIRE survey that have been processed by us and modified to simulate how the c2d observations would detect the extragalactic background. Changes from previous deliveries include location-dependent corrections for IRAC, 70 micron photometry, improved estimation of the uncertainties, "band-filling" of fluxes for sources seen at other wavelengths, and an improved classification system. While still imperfect, the new classification system should provide a much more secure set of young stellar (or substellar) objects. Note that this version is an update on previous versions and should be the reference for any use of c2d data products.

Available at Spitzer Science Center Site

The document can be obtained either from the Spitzer Science Center (http://ssc.spitzer.caltech.edu/legacy/c2dhistory.html) or from the c2d website (http://peggysue.as.utexas.edu/SIRTF/)

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.