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Abstracts of recently accepted papers

Giant planet migration, disk evolution, and the origin of transitional disks

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We present models of giant planet migration in evolving protoplanetary disks. Our disks evolve subject to viscous transport of angular momentum and photoevaporation, while planets undergo Type II migration. We use a Monte Carlo approach, running large numbers of models with a range in initial conditions. We find that relatively simple models can reproduce both the observed radial distribution of extra-solar giant planets, and the lifetimes and accretion histories of protoplanetary disks. The use of state-of-the-art photoevaporation models results in a degree of coupling between planet formation and disk clearing, which has not been found previously. Some accretion across planetary orbits is necessary if planets are to survive at radii $\lesssim$1.5AU, and if planets of Jupiter mass or greater are to survive in our models they must be able to form at late times, when the disk surface density in the formation region is low. Our model forms two different types of "transitional" disks, embedded planets and clearing disks, which show markedly different properties. We find that the observable properties of these systems are broadly consistent with current observations, and highlight useful observational diagnostics. We predict that young transition disks are more likely to contain embedded giant planets, while older transition disks are more likely to be undergoing disk clearing.

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Preprint available at `http://www.strw.leidenuniv.nl/~rda/publications.html` or `arXiv:0909.0004`

X-ray optical depth diagnostics of T Tauri accretion shocks

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In classical T Tauri stars, X-rays are produced by two plasma components: a hot low-density plasma, with frequent flaring activity, and a high-density lower temperature plasma. The former is coronal plasma related to the stellar magnetic activity. The latter component, never observed in non-accreting stars, could be plasma heated by the shock formed by the accretion process. However its nature is still being debated. Our aim is to probe the soft X-ray emission from the high-density plasma component in classical T Tauri stars to check whether this is plasma heated in the accretion shock or whether it is coronal plasma. High-resolution X-ray spectroscopy allows us to measure individual line fluxes. We analyze X-ray spectra of the classical T Tauri stars MP Muscae and TW Hydrae. Our aim is to evaluate line ratios to search for optical depth effects, which are expected in the accretion-driven scenario. We also derive the plasma emission measure distributions EMD, to investigate whether and how the EMD of accreting and non accreting young stars differ. The results are compared to those obtained for the non-accreting weak-line T Tauri star TWA 5. We find evidence of resonance scattering in the strongest lines of MP Mus, supporting the idea that soft X-rays are produced by plasma heated in the accretion shock. We also find that the EMD of MP Mus has two peaks: a cool peak at temperatures expected for plasma heated in the accretion shock, and a hot peak typical of coronal plasma. The shape of the EMD of MP Mus appears to be the superposition of the EMD of a pure coronal source, like TWA 5, and an EMD alike that of TW Hydrae, which is instead dominated by shock-heated plasma.

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Search for Keplerian periods in light variations of T Tauri stars and Herbig Ae stars

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Long-term homogeneous UBVR observations of T Tauri stars and Herbig Ae stars, collected at the Majdanak Observatory over 20 years (project ROTOR), are analysed. We found a linear relationship between the charateristic time of variability and the total bolometric luminosity of the 'star+disk' system: the larger the luminosity, the slower the variability. The relationship is valid over a wide range of masses and luminosities from T Tauri stars to Herbig Ae stars. It turns out that the characteristric time of variability is, on average, equal to 1/4 of the Keplerian period at the radius of dust sublimation known from interferometric observations. In some of the T Tauri stars, periods of 25 to 120 days were stable during several seasons of observations. The periods correspond to Keplerian orbits with semi-major axes within 1.14 to 0.52 AU. These data are indirect evidence of the protoplanet motions within the dusty circumstellar disks at the pre-main sequence stages of stellar evolution.

Accepted by Astronomy Reports

Hot high-mass accretion disk candidates

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To better understand the physical properties of accretion disks in high-mass star formation, we present a study of a dozen high-mass accretion disk candidates observed at high spatial resolution with the Australia Telescope Compact Array (ATCA) in the high-excitation (4,4) and (5,5) lines of NH_3. All of our originally selected sources were detected in both NH_3 transitions, directly associated with CH_3OH Class II maser emission and implying that high-excitation NH_3 lines are good tracers of the dense gas components in hot-core type targets. Only the one source that did not satisfy the initial selection criteria remained undetected. From the eleven mapped sources, six show clear signatures of rotation and/or infall motions. These signatures vary from velocity gradients perpendicular to the outflows, to infall signatures in absorption against ultracompact HII regions, to more spherical infall signatures in emission. Although our spatial resolution is $\sim$1000 AU, we do not find clear Keplerian signatures in any of the sources. Furthermore, we also do not find flattened structures. In contrast to this, in several of the sources with rotational signatures, the spatial structure is approximately spherical with sizes exceeding 10^4 AU, showing considerable clumpy sub-structure at even smaller scales. This implies that on average typical Keplerian accretion disks – if they exist as expected – should be confined to regions usually smaller than 1000 AU. It is likely that these disks are fed by the larger-scale rotating envelope structure we observe here. Furthermore, we do detect 1.25 cm continuum emission in most fields of view. While in some cases weak cm continuum emission is associated with our targets, more typically larger-scale HII regions are seen offset more than $10''$ from our sources. While these HII regions are unlikely to be directly related

to the target regions, this spatial association nevertheless additionally stresses that high-mass star formation rarely proceeds in an isolated fashion but in a clustered mode.

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

Dust retention in protoplanetary disks

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Context. Protoplanetary disks are observed to remain dust-rich for up to several million years. Theoretical modeling, on the other hand, raises several questions. Firstly, dust coagulation occurs so rapidly, that if the small dust grains are not replenished by collisional fragmentation of dust aggregates, most disks should be observed to be dust poor, which is not the case. Secondly, if dust aggregates grow to sizes of the order of centimeters to meters, they drift so fast inwards, that they are quickly lost.
Aims. We attempt to verify if collisional fragmentation of dust aggregates is effective enough to keep disks 'dusty' by replenishing the population of small grains and by preventing excessive radial drift.
Methods. With a new and sophisticated implicitly integrated coagulation and fragmentation modeling code, we solve the combined problem of coagulation, fragmentation, turbulent mixing and radial drift and at the same time solve for the 1-D viscous gas disk evolution.
Results. We find that for a critical collision velocity of 1 m/s, as suggested by laboratory experiments, the fragmentation is so effective, that at all times the dust is in the form of relatively small particles. This means that radial drift is small and that large amounts of small dust particles remain present for a few million years, as observed. For a critical velocity of 10 m/s, we find that particles grow about two orders of magnitude larger, which leads again to significant dust loss since larger particles are more strongly affected by radial drift.

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The Carnegie Astrometric Planet Search Program

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We are undertaking an astrometric search for gas giant planets and brown dwarfs orbiting nearby low mass dwarf stars with the 2.5-m du Pont telescope at the Las Campanas Observatory in Chile. We have built two specialized astrometric cameras, the Carnegie Astrometric Planet Search Cameras (CAPSCam-S and CAPSCam-N), using two Teledyne Hawaii-2RG HyViSI arrays, with the cameras' design having been optimized for high accuracy astrometry of M dwarf stars. We describe two independent CAPSCam data reduction approaches and present a detailed analysis of the observations to date of one of our target stars, NLTT 48256. Observations of NLTT 48256 taken since July 2007 with CAPSCam-S imply that astrometric accuracies of around 0.3 milliarcsec per hour are achievable, sufficient to detect a Jupiter-mass companion orbiting 1 AU from a late M dwarf 10 pc away with a signal-to-noise ratio of about 4. We plan to follow about 100 nearby (primarily within about 10 pc) low mass stars, principally late M, L, and T dwarfs, for 10 years or more, in order to detect very low mass companions with orbital periods long enough to permit the existence of habitable, Earth-like planets on shorter-period orbits. These stars are generally too faint and red to be included in ground-based Doppler planet surveys, which are often optimized for FGK dwarfs. The smaller masses

of late M dwarfs also yield correspondingly larger astrometric signals for a given mass planet. Our search will help to determine whether gas giant planets form primarily by core accretion or by disk instability around late M dwarf stars.

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Preprint available at http://www0.dtm.ciw.edu/boss/ftp/caps/

The JCMT Legacy Survey of the Gould Belt: a first look at Orion B with HARP

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The Gould Belt Legacy Survey will survey nearby star-forming regions (within 500 pc), using HARP (Heterodyne Array Receiver Programme), SCUBA-2 (Submillimetre Common-User Bolometer Array 2) and POL-2 (Polarimeter 2) on the James Clerk Maxwell Telescope (JCMT). This paper describes the initial data obtained using HARP to observe ^{12}CO, ^{13}CO and C^{18}O $J = 3 \rightarrow 2$ towards two regions in Orion B, NGC 2024 and NGC 2071. We describe the physical characteristics of the two clouds, calculating temperatures and opacities utilizing all three isotopologues. We find good agreement between temperatures calculated from CO and from dust emission in the dense, energetic regions. We determine the mass and energetics of the clouds, and of the high-velocity material seen in ^{12}CO emission, and compare the relative energetics of the high- and low-velocity material in the two clouds. We present a CLUMPFIND analysis of the ^{13}CO condensations. The slope of the condensation mass functions, at the high-mass ends, is similar to the slope of the initial mass function.

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Young T-Dwarf Candidates in IC 348

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The determination of the lower-end of the initial mass function (IMF) provides strong constraints on star formation theories. We report here on a search for isolated planetary-mass objects in the 3 Myr-old star-forming region IC 348. Deep, narrowband CH4off and CH4on images were obtained with CFHT/WIRCam over 0.11 sq.deg. in the central part of IC 348 to identify young T-dwarfs from their 1.6 um methane absorption bands. We report three faint T-dwarf candidates with CH4on-CH4off colours > 0.4 mag. Extinction was estimated for each candidate and lies in the range Av ∼5-12 mag. Comparisons with T-dwarf spectral models, and colour/colour and colour/magnitude diagrams, reject two of the three candidates because of their extreme z' - J blueness. The one remaining object is not thought to be a foreground field dwarf because of a number density argument and also its strong extinction Av - 12 mag, or thought to be a background field T-dwarf which would be expected to be much fainter. Models and diagrams give this object a preliminary T6 spectral type. With a few Jupiter masses, the young T-dwarf candidate reported here is potentially amongst the youngest, lowest mass objects detected in a star-forming region so far. Its frequency is consistent with the extrapolation of current lognormal IMF estimates down to the planetary mass domain.

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Low-mass protostars and dense cores in different evolutionary stages in IRAS 00213+6530

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Aims. The aim of this paper is to study with high angular resolution a dense core associated with a low-luminosity IRAS source, IRAS 00213+6530, in order to investigate whether low mass star formation is taking place in isolation.
Methods. We carried out observations at 1.2 mm with the IRAM 30 m telescope, and VLA observations in the continuum mode at 6 cm, 3.6 cm, 1.3 cm and 7 mm, together with H_2O maser and NH_3 lines toward IRAS 00213+6530. Additionally, we observed the CCS $J_N = 2_1$–1_0 transition, and H_2O maser emission using the NASA 70 m antenna at Robledo de Chavela, Spain. We studied the nature of the centimeter and millimeter emission of the young stellar objects (YSOs) found in the region, and the physical properties of the dense gas and dust emission.
Results. The centimeter and millimeter continuum emission, together with the near infrared data from 2MASS allowed us to identify three YSOs, IRS 1, VLA 8A, and VLA 8B, with different radio and infrared properties, and which seem to be in different evolutionary stages. IRS 1, detected only in the infrared, is in the more advanced stage. On the other hand, VLA 8A, bright at centimeter and millimeter wavelengths, coincides with a near infrared 2MASS source, whereas VLA 8B has no infrared emission associated with it and is in the earliest evolutionary stage. The overall structure of the NH_3 emission consists of three clouds. Two of these, MM1 and MM2, are associated with dust emission at millimeter wavelengths, while the southern cloud is only detected in NH_3. The YSOs are embedded in MM1, where we found evidence of line broadening and temperature enhancements. On the other hand, the southern cloud and MM2 appear to be quiescent and starless. Concerning the 1.2 mm dust emission, we modeled the radial intensity profile of MM1. The model fits the data reasonably well, but it underestimates the intensity at small projected distances from

the 1.2 mm peak, probably due to the presence of multiple YSOs embedded in the dusty envelope. There is a strong differentiation in the relative NH_3 abundance with low values of $\sim 2 \times 10^{-8}$ toward MM1, which harbors the YSOs, and high values, up to 10^{-6}, toward the southern cloud and MM2, suggesting that these clouds could be in a young evolutionary stage.
Conclusions. IRAS 00213+6530 harbors a multiple system of low-mass protostars, indicating that star formation in this cloud is taking place in groups or clusters, rather than in isolation. The low-mass YSOs found in IRAS 00213+6530 are in different evolutionary stages, suggesting that star formation takes place in different episodes.

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The Spitzer c2d Survey of Nearby Dense Cores VII: Chemistry and Dynamics in L43

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We present results from the Spitzer Space Telescope and molecular line observations of 9 species toward the dark cloud L43. The Spitzer images and molecular line maps suggest it has a starless core and a Class I protostar evolving in the same environment. CO depletion is seen in both sources, and DCO^+ lines are stronger toward the starless core. With a goal of testing the chemical characteristics from pre- to protostellar stages, we adopt an evolutionary chemical model to calculate the molecular abundances and compare with our observations. Among the different model parameters we tested, the best-fit model suggests a longer total timescale at the pre-protostellar stage, but with faster evolution at the later steps with higher densities.

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A submillimetre survey of the kinematics of the Perseus molecular cloud: I. data

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We present submillimetre observations of the $J = 3 \rightarrow 2$ rotational transition of ^{12}CO, ^{13}CO and $C^{18}O$ across over 600 arcmin^2 of the Perseus molecular cloud, undertaken with HARP, a new array spectrograph on the James Clerk Maxwell Telescope. The data encompass four regions of the cloud, containing the largest clusters of dust continuum condensations: NGC 1333, IC348, L1448 and L1455. A new procedure to remove striping artefacts from the raw HARP data is introduced. We compare the maps to those of the dust continuum emission mapped with SCUBA (Hatchell et al. 2005) and the positions of starless and protostellar cores (Hatchell et al. 2007). No straightforward correlation is found between the masses of each region derived from the HARP CO and SCUBA data, underlining the care that must be exercised when comparing masses of the same object derived from different tracers. From the $^{13}CO/C^{18}O$ line ratio the relative abundance of the two species ($[^{13}CO]/[C^{18}O] \sim 7$) and their opacities (typically τ is 0.02–0.22 and 0.15–1.52 for the $C^{18}O$ and ^{13}CO gas respectively) are calculated. $C^{18}O$ is optically thin nearly everywhere, increasing in opacity towards star-forming cores but not beyond $\tau_{18} \sim 0.9$. Assuming the ^{12}CO gas is optically thick we compute its excitation temperature, T_{ex} (around 8–30 K), which has little correlation with estimates of the dust temperature.

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Star Formation Activity in the Pipe Nebula

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The Pipe Nebula, a large nearby molecular cloud lacks obvious signposts of star formation in all but one of more than 130 dust extinction cores that have been identified within it. In order to quantitatively determine the current level of star formation activity in the Pipe Nebula, we analyzed 13 square degrees of sensitive mid-infrared maps of the entire cloud, obtained with the Multiband Imaging Photometer for Spitzer (MIPS) at wavelengths of 24 μm and 70 μm to search for candidate Young Stellar Objects (YSOs) in the high-extinction regions. We argue that our search is complete for class I and typical class II YSOs with luminosities of $L_{\rm bol} \sim 0.2\,L_\odot$ and greater. We find only 18 candidate YSOs in the high-extinction regions of the entire Pipe cloud. Twelve of these sources are previously known members of a small cluster associated with Barnard 59, the largest and most massive dense core in the cloud. With only six candidate class I and class II YSOs detected towards extinction cores outside of this cluster, our findings emphatically confirm the notion of an extremely low level of star formation activity in the Pipe Nebula. The resulting star formation efficiency for the entire cloud mass is only $\sim 0.06\%$.

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Disk Evolution in the Three Nearby Star-Forming Regions of Taurus, Chamaeleon, and Ophiuchus

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We analyze samples of *Spitzer* Infrared Spectrograph (IRS) spectra of T Tauri stars in the Ophiuchus, Taurus, and Chamaeleon I star-forming regions, whose median ages lie in the <1 to 2 Myr range. The median mid-infrared spectra of objects in these three regions are similar in shape, suggesting, on average, similar disk structures. When normalized to the same stellar luminosity, the medians follow each other closely, implying comparable mid-infrared excess emission from the circumstellar disks. We use the spectral index between 13 and 31 μm and the equivalent width of the 10 μm silicate emission feature to identify objects whose disk configuration departs from that of a continuous, optically thick accretion disk. Transitional disks, whose steep 13-31 μm spectral slope and near-IR flux deficit reveal inner disk clearing, occur with about the same frequency of a few percent in all three regions. Objects with unusually large 10 μm equivalent widths are more common (20-30%); they could reveal the presence of disk gaps filled with optically thin dust. Based on their medians and fraction of evolved disks, T Tauri stars in Taurus and Chamaeleon I are very alike. Disk evolution sets in early, since already the youngest region, the Ophiuchus core (L1688), has more settled disks with larger grains. Our results indicate that protoplanetary disks show clear signs of dust evolution at an age of a few Myr, even as early as ~ 1 Myr, but age is not the only factor determining the degree of evolution during the first few million years of a disk's lifetime.

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Time-Evolution of Viscous Circumstellar Disks due to Photoevaporation by FUV, EUV and X-ray Radiation from the Central Star

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We present the time evolution of viscously accreting circumstellar disks as they are irradiated by ultraviolet and X-ray photons from a low-mass central star. Our model is a hybrid of a 1D time-dependent viscous disk model coupled to a 1+1D disk vertical structure model used for calculating the disk structure and photoevaporation rates. We find that disks of initial mass $0.1M_\odot$ around $\sim 1M_\odot$ stars survive for $\sim 4 \times 10^6$ years, assuming a viscosity parameter $\alpha = 0.01$, a time-dependent FUV luminosity $L_{FUV} \sim 10^{-2} - 10^{-3}$ $L_\odot$ and with X-ray and EUV luminosities $L_X \sim L_{EUV} \sim 10^{-3} L_\odot$. We find that FUV/X-ray-induced photoevaporation and viscous accretion are both important in depleting disk mass. Photoevaporation rates are most significant at $\sim$ 1-10 AU and at $\gtrsim$ 30 AU. Viscosity spreads the disk which causes mass loss by accretion onto the central star and feeds mass loss by photoevaporation in the outer disk. We find that FUV photons can create gaps in the inner, planet-forming regions of the disk ($\sim 1 - 10$ AU) at relatively early epochs in disk evolution while disk masses are still substantial. EUV and X-ray photons are also capable of driving gaps, but EUV can only do so at late, low accretion-rate epochs after the disk mass has already declined substantially. Disks around stars with predominantly soft X-ray fields experience enhanced photoevaporative mass loss. We follow disk evolution around stars of different masses, and find that disk survival time is relatively independent of mass for stars with $M_* \leq 3M_\odot$; for $M_* > 3M_\odot$ the disks are short-lived($\sim 10^5$ years).

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Rotational excitation of methylidynium (CH^+) by a helium atom at high temperature

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We aim to obtain accurate rate coefficients for the collisional excitation of CH^+ by He for high gas temperatures. The *ab initio coupled-cluster* [CCSD(T)] approximation was used to compute the interaction potential energy. Cross sections are then derived in the close coupling (CC) approach and rate coefficients inferred by averaging these cross sections over a Maxwell-Boltzmann distribution of kinetic energies. Cross sections are calculated up to $10\,000\,\mathrm{cm}^{-1}$ for J ranging from 0 to 10. Rate coefficients are obtained at high temperatures up to 2000 K.

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Disk formation during collapse of magnetized protostellar cores

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In the context of star and planet formation, understanding the formation of disks is of fundamental importance. Previous studies found that the magnetic field has a very strong impact on the collapse of a prestellar cloud, particularly in possibly suppressing the formation of a disk even for relatively modest values of the magnetic intensity. Since observations infer that cores have a substantial level of magnetization, this raises the question of how disks form. However, most studies have been restricted to the case in which the initial angle, α, between the magnetic field and the rotation axis equals 0°. We explore and analyse the influence of non aligned configurations on disk formation. We perform 3D ideal MHD, AMR numerical simulations for various values of μ, the ratio of the mass-to-flux to the critical mass-to-flux, and various values of α. We find that disks form more easily as α increases from 0 to 90°. We propose that as the magnetized pseudo-disks become thicker with increasing α, the magnetic braking efficiency is lowered. We also find that even small values of α ($\simeq$ 10-20°) show significant differences with the alligned case. Within the framework of ideal MHD and for our choice of initial conditions, centrifugally supported disks cannot form for values of μ smaller than $\simeq$3, if the magnetic field and the rotation axis are perpendicular, and smaller than about $\simeq$5-10 when they are perfectly aligned.

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Analytical theory for the initial mass function: II. Properties of the flow.

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Recently, Hennebelle and Chabrier (2008) derived an analytical theory for the mass spectrum of non self-gravitating clumps associated with overdensities in molecular clouds and for the initial mass function of gravitationally bound prestellar cores, as produced by the turbulent collapse of the cloud. In this companion paper, we examine the effects of the non-isothermality of the flow, of the turbulence forcing and of local fluctuation of the velocity dispersion, on the mass function. In particular, we investigate the influence of a polytropic equation of state and of the effective adiabatic exponent γ and find that it has a drastic influence on the low mass part of the IMF. We also consider a barotropic equation of state (i.e. a piecewise polytropic eos) that mimics the thermal behaviour of the molecular gas and compare the prediction of our theory with the results of numerical simulations and with the observationally-derived IMF, for cloud parameters which satisfy Larson's type relations. We find that for clouds whose density is, at all scales, almost an order of magnitude larger than the density inferred for the CO clumps in the Galaxy, a good agreement is obtained between the theory and the observed IMF, suggesting that star formation preferentially occurs in high density environments. We derive an analytical expression for the IMF which generalizes the expression previously obtained for the isothermal case. This easy-to-implement analytical IMF should serve as a template to compare observational or numerical results with the theory.

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A Mapping Survey of Dense Clumps Associated with Embedded Clusters: Evolutionary Stages of Cluster-Forming Clumps

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We have carried out a survey of the dense clumps associated with 14 embedded clusters in the $C^{18}O$ (J=1–0) line emission with the Nobeyama 45m telescope in order to understand the formation and evolution of stellar clusters in dense clumps of molecular clouds. We have selected these clusters at distances from 0.3 to 2.1 kpc and have mapped about $6' \times 6'$ to $10' \times 10'$ regions (corresponding to 3.8 pc × 3.8 pc at 2.1 kpc) for all the clumps with $22''$ resolution (corresponding to Jeans length at 2.1 kpc). We have obtained dense clumps with radii of 0.40–1.6 pc, masses of 150–4600 $M_\odot$, and velocity widths in FWHM of 1.4–3.3 $\mathrm{km\,s^{-1}}$. Most of the clumps are found to be approximately in virial

equilibrium, which implies that $C^{18}O$ gas represents parental dense clumps for cluster formation. From the spatial relation between the distributions of clumps and clusters, we classified $C^{18}O$ clumps into three types (*Type A*, *B*, and *C*). The $C^{18}O$ clumps as classified into *Type A* have emission distributions with a single peak at the stellar clusters and higher brightness contrast than that of other target sources. *Type B* clumps have double or triple peaks which are associated with the cluster and moderately high brightness contrast structure. *Type C* clumps have also multiple peaks although they are not associated with the cluster and low brightness contrast structure. We suggest that our classification represents an evolutionary trend of cluster-forming dense clumps because dense gas in molecular clouds is expected to be converted into stellar constituents, or to be dispersed by stellar activities. Moreover, although there is a scatter, we found a tendency that the SFEs of the dense clumps increase from *Type A* to *Type C*, which also supports our scenario.

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Stringent Limits on the Polarized Submillimeter Emission from Protoplanetary Disks

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We present arcsecond-resolution Submillimeter Array (SMA) polarimetric observations of the 880 μm continuum emission from the protoplanetary disks around two nearby stars, HD 163296 and TW Hydrae. Although previous observations and theoretical work have suggested that a 2-3% polarization fraction should be common for the millimeter continuum emission from such disks, we detect no polarized continuum emission above a 3σ upper limit of 7 mJy in each arcsecond-scale beam, or $< 1\%$ in integrated continuum emission. We compare the SMA upper limits with the predictions from the exploratory Cho & Lazarian (2007) model of polarized emission from T Tauri disks threaded by toroidal magnetic fields, and rule out their fiducial model at the $\sim 10\sigma$ level. We explore some potential causes for this discrepancy, focusing on model parameters that describe the shape, magnetic field alignment, and size distribution of grains in the disk. We also investigate related effects like the magnetic field strength and geometry, scattering off of large grains, and the efficiency of grain alignment, including recent advances in grain alignment theory, which are not considered in the fiducial model. We discuss the impact each parameter would have on the data and determine that the suppression of polarized emission plausibly arises from rounding of large grains, reduced efficiency of grain alignment with the magnetic field, and/or some degree of magnetic field tangling (perhaps due to turbulence). A poloidal magnetic field geometry could also reduce the polarization signal, particularly for a face-on viewing geometry like the TW Hya disk. The data provided here offer the most stringent limits to date on the polarized millimeter-wavelength emission from disks around young stars.

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http://www.cfa.harvard.edu/~mhughes/download/hughes_pol.pdf

Far-Ultraviolet H_2 Emission from Circumstellar Disks

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We analyze the far-ultraviolet (FUV) spectra of 33 classical T Tauri stars (CTTS), including 20 new spectra obtained with the Advanced Camera for Surveys Solar Blind Channel (ACS/SBC) on the Hubble Space Telescope. Of the sources, 28 are in the ∼1 Myr old Taurus-Auriga complex or Orion Molecular Cloud, 4 in the 8-10 Myr old Orion OB1a complex and one, TW Hya, in the 10 Myr old TW Hydrae Association. We also obtained FUV ACS/SBC spectra of 10 non-accreting sources surrounded by debris disks with ages between 10 and 125 Myr. We use a feature in the FUV spectra due mostly to electron impact excitation of H_2 to study the evolution of the gas in the inner disk. We find that the H_2 feature is absent in non-accreting sources, but is detected in the spectra of CTTS and correlates with accretion luminosity. Since all young stars have active chromospheres which produce strong X-ray and UV emission capable of exciting H_2 in the disk, the fact that the non-accreting sources show no H_2 emission implies that the H_2 gas in the inner disk has dissipated in the non-accreting sources, although dust (and possibly gas) remains at larger radii. Using the flux at 1600 Å, we estimate that the column density of H_2 left in the inner regions of the debris disks in our sample is less than $\sim 3 \times 10^{-6}$ g cm^{-2}, nine orders of magnitude below the surface density of the minimum mass solar nebula at 1 AU.

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Unveiling the main heating sources in the Cepheus A HW2 region

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We present high angular resolution PdBI images (beam of ∼0.33″) of the J=27→26 line from several vibrational levels (v_7=1 and v_6=1) of HC_3N toward Cepheus A HW2. These images reveal the two main heating sources in the cluster: one centered in the disk collimating the HW2 radio jet (the HW2 disk), and the other associated with a hot core 0.3″ northeast HW2 (the HC). This is the first time that vibrationally excited emission of HC_3N is spatially resolved in a disk. The kinematics of this emission shows that the HW2 disk rotates following a Keplerian law. We derive the temperature profiles in the two objects from the excitation of HC_3N along the HW2 disk and the HC. These profiles reveal that both objects are centrally heated and show temperature gradients. The inner and hotter regions have temperatures of 350±30 K and 270±20 K for the HW2 disk and the HC, respectively. In the cooler and outer regions, the temperature drops to 250±30 K in the HW2 disk, and to 220±15 K in the HC. The estimated luminosity of the heating source of the HW2 disk is $\sim 2.2 \times 10^4\,L_\odot$, and $\sim 3000\,L_\odot$ for the HC. The most massive protostar in the HW2 region is the powering source of the HW2 radio jet. We discuss the formation of multiple systems in this cluster. The proximity of the HC to HW2 suggest that these sources likely form a binary system of B stars, explaining the observed precession of the HW2 radio jet.

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Particle Clumping and Planetesimal Formation Depend Strongly on Metallicity

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We present three-dimensional numerical simulations of particle clumping and planetesimal formation in protoplanetary disks with varying amounts of solid material. As centimeter-size pebbles settle to the mid-plane, turbulence develops through vertical shearing and streaming instabilities. We find that when the pebble-to-gas column density ratio is 0.01, corresponding roughly to solar metallicity, clumping is weak, so the pebble density rarely exceeds the gas density. Doubling the column density ratio leads to a dramatic increase in clumping, with characteristic particle densities more than ten times the gas density and maximum densities reaching several thousand times the gas density. This is consistent with unstratified simulations of the streaming instability that show strong clumping in particle dominated flows. The clumps readily contract gravitationally into interacting planetesimals of order 100 km in radius. Our results suggest that the correlation between host star metallicity and exoplanets may reflect the early stages of planet formation. We further speculate that initially low metallicity disks can be particle enriched during the gas dispersal phase, leading to a late burst of planetesimal formation.

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Wind-driving protostellar accretion discs. I. Formulation and parameter constraints

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We study a model of weakly ionized, protostellar accretion discs that are threaded by a large-scale, ordered magnetic field and power a centrifugally driven wind. We consider the limiting case where the wind is the main repository of the excess disc angular momentum and generalize the radially localized disc model of Wardle & Königl (1993), which focussed on the ambipolar diffusion regime, to other field diffusivity regimes, notably Hall and Ohm. We present a general formulation of the problem for nearly Keplerian, vertically isothermal discs using both the conductivity-tensor and the multi-fluid approaches and simplify it to a normalized system of ordinary differential equations in the vertical space coordinate. We determine the relevant parameters of the problem and investigate, using the vertical-hydrostatic-equilibrium approximation and other simplifications, the parameter constraints on physically viable solutions for discs in which the neutral particles are dynamically well coupled to the field already at the midplane. When the charged particles constitute a two-component ion–electron plasma one can identify four distinct sub-regimes in the parameter domain where the Hall diffusivity dominates and three sub-regimes in the Ohm-dominated domain. Two of the Hall sub-regimes can be characterized as being ambipolar diffusion-like and two as being Ohm-like: The properties of one member of the first pair of sub-regimes are identical to those of the ambipolar diffusion regime, whereas one member of the second pair has the same characteristics as one of the Ohm sub-regimes. All the Hall sub-regimes have $B_{r\mathrm{b}}/|B_{\phi\mathrm{b}}|$ (ratio of radial-to-azimuthal magnetic field amplitudes at the disc surface) > 1, whereas in two Ohm sub-regimes this ratio is < 1. When the two-component plasma consists instead of positively and negatively charged grains of equal mass, the entire Hall domain and one of the Ohm sub-regimes with $B_{r\mathrm{b}}/|B_{\phi\mathrm{b}}| < 1$ disappear. All viable solutions require the midplane neutral–ion momentum exchange time to be shorter than the local orbital time. We also infer that vertical magnetic squeezing always dominates over gravitational tidal compression in this model. In a follow-up paper we will present exact solutions that test the results of this analysis in the Hall regime.

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On the Emergent Spectra of Hot Protoplanet Collision Afterglows

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We explore the appearance of terrestrial planets in formation by studying the emergent spectra of hot molten protoplanets during their collisional formation. While such collisions are rare, the surfaces of these bodies may remain hot at temperatures of 1000-3000 K for up to millions of years during the epoch of their formation (of duration 10-100 Myr). These object are luminous enough in the thermal infrared to be observable with current and next generation optical/IR telescopes, provided that the atmosphere of the forming planet permits astronomers to observe brightness temperatures approaching that of the molten surface. Detectability of a collisional afterglow depends on properties of the planet's atmosphere – primarily on the mass of the atmosphere. A planet with a thin atmosphere is more readily detected, because there is little atmosphere to obscure the hot surface. Paradoxically, a more massive atmosphere prevents one from easily seeing the hot surface, but also keeps the planet hot for a longer time. In terms of planetary mass, more massive planets are also easier to detect than smaller ones because of their larger emitting surface areas – up to a factor of 10 in brightness between 1 and 10 M_{Earth} planets. We present preliminary calculations assuming a range of protoplanet masses (1-10 M_{Earth}), surface pressures (1-1000 bar), and atmospheric compositions, for molten planets with surface temperatures ranging from 1000 to 1800 K, in order to explore the diversity of emergent spectra that are detectable. While current 8- to 10-m class ground-based telescopes may detect hot protoplanets at wide orbital separations beyond 30 AU (if they exist), we will likely have to wait for next-generation extremely large telescopes or improved diffraction suppression techniques to find terrestrial planets in formation within several AU of their host stars.

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Young Stars and Protostellar Cores near NGC 2023

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We investigate the young (proto)stellar population in NGC 2023 and the L 1630 molecular cloud bordering the H II region IC 434, using Spitzer IRAC and MIPS archive data, JCMT SCUBA imaging and spectroscopy as well as targeted BIMA observations of one of the Class 0 protostars, NGC 2023 MM 1. We study the distribution of gas, dust and young stars in this region to see where stars are forming, whether the expansion of the H II region has triggered star formation, and whether dense cold cores have already formed stars. We have performed photometry of all IRAC and MIPS images, and used color-color diagrams to identify and classify all young stars seen within a $22' \times 26'$ field along the boundary between IC 434 and L 1630. For some stars, which have sufficient optical, IR, and/or sub-millimeter data we have also used the online SED fitting tool for a large 2D archive of axisymmetric radiative transfer models to perform more detailed modeling of the observed SEDs. We identify 5 sub-millimeter cores in our 850 and 450 μm SCUBA images, two of which have embedded class 0 or I protostars. Observations with BIMA are used to refine the position and characteristics of the Class 0 source NGC 2023 MM 1. These observations show that it is embedded in a very cold cloud core, which is strongly enhanced in NH_2D. We find that HD 37903 is the most massive member of a cluster with $20 - 30$ PMS stars. We also find smaller groups of PMS stars formed from the Horsehead nebula and another elephant trunk structure to the north of the Horsehead. Star formation is also occurring in the dark lane seen in IRAC images and in the sub-millimeter continuum. We refine the spectral classification of HD 37903 to B2 Ve. We find that the star has a clear IR excess, and therefore it is a young Herbig Be star. Our study shows that the expansion of the IC 434 H II region has triggered star formation in some of the dense elephant trunk structures and compressed gas inside the L 1630 molecular cloud. This pre-shock region is seen as a sub-millimeter ridge in which stars have already formed. The cluster associated with NGC 2023 is very young, and has a large fraction of Class I sources.

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Testing Molecular-Cloud Fragmentation Theories: Self-Consistent Analysis of OH Zeeman Observations

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The ambipolar-diffusion theory of star formation predicts the formation of fragments in molecular clouds with mass-to-flux ratios greater than that of the parent-cloud envelope. By contrast, scenarios of turbulence-induced fragmentation do not yield such a robust prediction. Based on this property, Crutcher et al. (2009) proposed an observational test that could potentially discriminate between fragmentation theories. However, the analysis applied to the data severely restricts the discriminative power of the test: the authors conclude that they can only constrain what they refer to as the "idealized" ambipolar-diffusion theory that assumes initially straight-parallel magnetic field lines in the parent cloud. We present an original, self-consistent analysis of the same data taking into account the nonuniformity of the magnetic field in the cloud envelopes, which is suggested by the data themselves, and we discuss important geometrical effects that must be accounted for in using this test. We show quantitatively that the quality of current data does not allow for a strong conclusion about any fragmentation theory. Given the discriminative potential of the test, we urge for more and better-quality data.

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On Hydrodynamic Motions in Dead Zones

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We investigate fluid motions near the midplane of vertically stratified accretion disks with highly resistive midplanes. In such disks, the magnetorotational instability drives turbulence in thin layers surrounding a resistive, stable dead zone. The turbulent layers in turn drive motions in the dead zone. We examine the properties of these motions using three-dimensional, stratified, local, shearing-box, non-ideal, magnetohydrodynamical simulations. Although the turbulence in the active zones provides a source of vorticity to the midplane, no evidence for coherent vortices is found in our simulations. It appears that this is because of strong vertical oscillations in the dead zone. By analyzing time series of azimuthally-averaged flow quantities, we identify an axisymmetric wave mode particular to models with dead zones. This mode is reduced in amplitude, but not suppressed entirely, by changing the equation of state from isothermal to ideal. These waves are too low-frequency to affect sedimentation of dust to the midplane, but may have significance for the gravitational stability of the resulting midplane dust layers.

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Disc-planet interactions in sub-keplerian discs

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One class of protoplanetary disc models, the X-wind model, predicts strongly subkeplerian orbital gas velocities, a configuration that can be sustained by magnetic tension. We investigate disc-planet interactions in these subkeplerian discs, focusing on orbital migration for low-mass planets and gap formation for high-mass planets. We use linear calculations and nonlinear hydrodynamical simulations to measure the torque and look at gap formation. In both

cases, the subkeplerian nature of the disc is treated as a fixed external constraint. We show that, depending on the degree to which the disc is subkeplerian, the torque on low-mass planets varies between the usual Type I torque and the one-sided outer Lindblad torque, which is also negative but an order of magnitude stronger. In strongly subkeplerian discs, corotation effects can be ignored, making migration fast and inward. Gap formation near the planet's orbit is more difficult in such discs, since there are no resonances close to the planet accommodating angular momentum transport. In stead, the location of the gap is shifted inwards with respect to the planet, leaving the planet on the outside of a surface density depression. Depending on the degree to which a protoplanetary disc is subkeplerian, disc-planet interactions can be very different from the usual Keplerian picture, making these discs in general more hazardous for young planets.

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A Two Micron All Sky Survey Analysis of the Stability of Southern Bok Globules

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We used near-infrared Two Micron All Sky Survey data to construct visual extinction maps of a sample of Southern Bok globules utilizing the NICE method. We derived radial extinction profiles of dense cores identified in the globules and analyzed their stability against gravitational collapse with isothermal Bonnor-Ebert spheres. The frequency distribution of the stability parameter (ξ_{max}) of these cores shows that a large number of them are located in stable states, followed by an abrupt decrease of cores in unstable states. This decrease is steeper for globules with associated *IRAS* point sources than for starless globules. Moreover, globules in stable states have a Bonnor-Ebert temperature of $T = 15 \pm 6$ K, while the group of critical plus unstable globules has a different temperature of $T = 10 \pm 3$ K. Distances were estimated to all the globules studied in this work and the spectral class of the *IRAS* sources was calculated. No variations were found in the stability parameters of the cores and the spectral class of their associated *IRAS* sources. On the basis of ^{13}CO $J = 1$–0 molecular line observations, we identified and modeled a blue-asymmetric line profile toward a globule of the sample, obtaining an upper limit infall speed of 0.25 km s^{-1}.

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High Resolution Near-Infrared Survey of the Pipe Nebula. I. A Deep Infrared Extinction Map of Barnard 59

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We present our analysis of a fully sampled, high resolution dust extinction map of the Barnard 59 complex in the Pipe Nebula. The map was constructed with the infrared color excess technique applied to a photometric catalog that combines data from both ground and space based observations. The map resolves for the first time the high density center of the main core in the complex, that is associated with the formation of a small cluster of stars. We found that the central core in Barnard 59 shows an unexpected lack of significant substructure consisting of only two significant fragments. Overall, the material appears to be consistent with being a single, large core with a density profile that can be well fit by a King model. A series of NH_3 pointed observations towards the high column density center of the core appear to show that the core is still thermally dominated, with sub-sonic non-thermal motions. The stars in the cluster could be providing feedback to support the core against collapse, but the relatively narrow radio lines suggest that an additional source of support, for example a magnetic field, may be required to stabilize the core. Outside the central core our observations reveal the structure of peripheral cores and resolve an extended filament into a handful of significant substructures whose spacing and masses appear to be consistent with Jeans fragmentation.

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The Simultaneous Formation of Massive Stars and Stellar Clusters

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We show that massive stars and stellar clusters are formed simultaneously, the global evolution of the forming cluster is what allows the central stars to become massive. We predict that massive star forming clumps, such as those observed in Motte et al. 2007, contract and grow in mass leading to the formation of massive stars. This occurs as mass is continually channeled from large radii onto the central proto-stars, which can become massive through accretion. Using SPH simulations of massive star forming clumps in a Giant Molecular Cloud, we show that clumps are initially diffuse and filamentary, and become more concentrated as they collapse. Simulated interferometry observations of our data provide an explanation as to why young massive star forming regions show more substructure than older ones. The most massive stars in our model are found within the most bound cluster. Most of the mass accreted by the massive stars was originally distributed throughout the clump at low densities, and was later funneled to the star due to global in-fall. Even with radiative feedback no massive pre-stellar cores are formed. The original cores are of intermediate mass and gain their additional mass in the proto-stellar stage. We also find that cores which form low mass stars exist within the volume from which the high mass stars accrete, but are largely unaffected by this process.

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The Hot and Clumpy Molecular Cocoon Surrounding the Ultracompact HII Region G5.89−0.39

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We present observations of CH_3CN (12−11) emission at a resolution of ∼2" toward the shell-like ultracompact H_2region G5.89−0.39 with the Submillimeter Array. The integrated CH_3CN emission reveals dense and hot molecular cocoon in the periphery of the H_2region G5.89−0.39, with a CH_3CN deficient region roughly centered at G5.89−0.39. By analyzing the CH_3CN emission using population diagram analysis, we find, for the first time, a decreasing temperature structure from 150 to 40 K with the projected distance from Feldt's star, which is thought to be responsible for powering the H_2region. Our results further indicate that the majority of the heating energy in the observed dense gas is supplied by the Feldt's star. From the derived CH_3CN column density profile, we conclude that the dense gas is not uniformly-distributed but centrally-concentrated, with a power-law exponent of 5.5 for $r < 8000$ AU, and 2.0 for 8000 AU $< r <$ 20000 AU, where r is the distance to Feldt's star. The estimated large power index of 5.5 can be attributed to an enhancement of CH_3CN abundance in the close vicinity of Feldt's star.

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Evolutionary Status of Brightest and Youngest Source in the Orion Molecular Cloud-3 Region

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The brightest continuum source in the Orion Molecular Cloud-3 region (OMC-3), MMS 6, was observed with the Very Large Array (VLA), the Nobeyama Millimeter Array (NMA), and the Submillimeter Array (SMA). Our data were supplemented by near- to mid-infrared archival data taken by Spitzer Space Telescope. The compact continuum source, MMS 6-main, was detected with an H_2 mass of 3.0 $M_\odot$ with a size of 510 AU. Despite its compact and well condensed appearance, neither clear CO outflow, radio jet, nor infrared sources (at a wave-length shorter than 8 μm) were detected at MMS 6-main even with the present high-spatial resolution and high-sensitivity observations. The derived H_2 column density, 2.6×10^{25} cm^{-2}, corresponds to a visual extinction of $A_v\sim15000$ mag., and the derived number density is at least two orders of magnitude higher than for the other OMC-2/3 continuum sources. The volume density profile of the source was estimated to have a power-law index of 2 or steeper down to a radius of $\sim$450 AU. The time scale to form a protostar at the center or the time scale elapsed after its formation is estimated to be 830 to 7600 yr. This is much shorter than the typical lifetime of the Class 0/I protostars, which is $\sim10^{(4-5)}$ yr, suggesting that MMS 6-main is probably in either the earliest stage of the proto-stellar core or in the latest stage of the pre-stellar phase.

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Statistical Assessment of Shapes and Magnetic Field Orientations in Molecular Clouds through Polarization Observations

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We present a novel statistical analysis aimed at deriving the intrinsic shapes and magnetic field orientations of molecular clouds using dust emission and polarization observations by the Hertz polarimeter. Our observables are the aspect ratio of the projected plane-of-the-sky cloud image, and the angle between the mean direction of the plane-of-the-sky component of the magnetic field and the short axis of the cloud image. To overcome projection effects due to the unknown orientation of the line-of-sight, we combine observations from 24 clouds, assuming that line-of-sight orientations are random and all are equally probable. Through a weighted least-squares analysis, we find that the best-fit intrinsic cloud shape describing our sample is an oblate disk with only small degrees of triaxiality. The best-fit intrinsic magnetic field orientation is close to the direction of the shortest cloud axis, with small (24 deg) deviations toward the long/middle cloud axes. However, due to the small number of observed clouds, the power of our analysis to reject alternative configurations is limited.

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Energetic Protons, Radionuclides and Magnetic Activity in Protostellar Disks

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We calculate the location of the magnetically-inactive dead zone in the minimum-mass protosolar disk, under ionization scenarios including stellar X-rays, long- or short-lived radionuclide decay, and energetic protons arriving from the

general interstellar medium, from a nearby supernova explosion, from the disk corona, or from the corona of the young star. The disk contains a dead zone in all scenarios except those with small dust grains removed and a fraction of the short-lived radionuclides remaining in the gas. All the cases without exception have an "undead zone" where intermediate resistivities prevent magneto-rotational turbulence while allowing shear-generated large-scale magnetic fields. The mass column in the undead zone is typically greater than the column in the turbulent surface layers. The results support the idea that the dead and undead zones are robust consequences of cold, dusty gas with mass columns exceeding 1000 g cm^{-2}.

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Observational study of sites of triggered star formation. CO and mid-infrared observations

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Context: Bright-rimmed clouds (BRCs) are isolated molecular clouds located on the edges of evolved HII regions. Star formation within these clouds may have been triggered through the propagation of photoionisation-induced shocks driven by the expansion of the HII region.
Aims: The main focus of this paper is to investigate the current level of star formation within a sample of southern hemisphere BRCs and evaluate to what extent, if any, star formation may have been triggered.
Methods: In this paper we present the results of a programme of position-switched CO observations towards 45 southern BRCs. The ^{12}CO, ^{13}CO and $C^{18}O$ J = 1–0 rotational transitions were simultaneously observed using the 22-m Mopra telescope. We complement these observations with archival mid-infrared data obtained from the MSX and Spitzer, as well as submillimetre and radio data previously reported in the literature. Combining all of the available data with the observations presented here allows us to build up a comprehensive picture of the current level of star formation activity within a significant number of BRCs.
Results: Analysis of the CO, mid-infrared and radio data result in the clouds being divided into three distinct groups: a) clouds that appear to be relatively unaffected by the photoionisation from the nearby OB star(s); b) clouds that show evidence of significant interaction between the molecular material and the HII regions; c) clouds towards which no CO emission is detected, but are associated with strong ionisation fronts; these are thought to be examples of clouds undergoing an ionisation flash. We refer to these groups as spontaneous, triggered, and zapped clouds, respectively. Comparing the physical parameters of spontaneous and triggered samples we find striking differences in luminosity, surface temperature and column density with all three quantities significantly enhanced for the clouds considered to have been triggered. Furthermore, we find strong evidence for star formation within the triggered sample by way of methanol and H_2O masers, embedded mid-infrared point sources and CO wings, however, we find evidence of ongoing star formation within only two of the spontaneous sample.
Conclusions: We have used CO, mid-infrared and radio data to identify 24 of the 45 southern BRCs that are undergoing a strong interaction with their HII region. We can therefore exclude the other 21 sources (∼50%) from future studies of triggered star formation. Fourteen of the 24 interacting BRCs are found to be associated with embedded mid-infrared point sources and we find strong evidence that these clouds are forming stars. The absence of mid-infrared sources towards the remaining ten clouds and the lack of any other evidence of star formation within these clouds leads us to conclude that these represent an earlier evolutionary stage of star formation.

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The RMS Survey: 6 cm continuum VLA observations towards candidate massive YSOs in the northern hemisphere

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Context: The Red MSX Source (RMS) survey is an ongoing multi-wavelength observational programme designed to return a large, well-selected sample of massive young stellar objects (MYSOs). We have identified ∼2000 MYSO candidates located throughout the Galaxy by comparing the colours of MSX and 2MASS point sources to those of known MYSOs. The aim of these follow-up observations is to identify other objects with similar colours such as ultra compact (UC) HII regions, evolved stars and planetary nebulae (PNe) and distinguish between genuine MYSOs and nearby low-mass YSOs.
Aims: To identify the populations of UCHII regions and PNe within the sample and examine their Galactic distribution.
Methods: We have conducted high resolution radio continuum observations at 6 cm towards 659 MYSO candidates in the northern hemisphere ($10^{\rm o} < l < 250^{\rm o}$) using the Very Large Array (VLA). These observations have a spatial resolution of ∼1–2″ and typical image r.m.s. noise values of ∼0.22 mJy − sensitive enough to detect a HII region powered by B0.5 star at the far side of the Galaxy. In addition to these targeted observations we present archival data towards a further 315 RMS sources extracted from a previous VLA survey of the inner Galaxy.
Results: We present the results of radio continuum observations made towards 974 MYSO candidates, 272 (∼27% of the observed sample) of which are found to be associated with radio emission above a 4σ detection limit (∼1 mJy). Using results from other parts of our multi-wavelength survey we separate these RMS-radio associations into two distinct types of objects, classifying 51 as PNe and a further 208 as either compact or UC HII regions. Including all HII regions and PNe identified either from the literature or from the multi-wavelength data these numbers increase to 391 and 79, respectively. Using this well selected sample of HII regions we estimate their Galactic scale height to be 0.6° radio emission of ≤1 mJy for the 702 non-detections, which is below the level expected if they had already begun to ionise their surroundings.
Conclusions: Using radio continuum and archival data we have identified 79 PNe and 391 HII regions within the northern RMS catalogue. We estimate the total fraction of contamination by PNe in the RMS sample is of order 10%. The sample of HII regions is probably the best representation to date of the Galactic population of HII regions as a whole.

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The RMS Survey: H_2O masers towards a sample of southern hemisphere massive YSO candidates and ultra compact HII regions

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Context: The Red MSX Source (RMS) survey has identified a large sample of candidate massive young stellar objects (MYSOs) and ultra compact (UC) HII regions from a sample of ∼2000 MSX and 2MASS colour selected sources.

Aims: To search for H_2O masers towards a large sample of young high mass stars and to investigate the statistical correlation of H_2O masers with the earliest stages of massive star formation.
Methods: We have used the Mopra Radio telescope to make position-switched observations towards ~500 UCHII regions and MYSOs candidates identified from the RMS survey and located between $190^o < l < 30^o$. These observations have a 4σ sensitivity of ~1 Jy and a velocity resolution of ~0.4 km s^{-1}.
Results: We have detected 163 H_2O masers, approximately 75% of which were previously unknown. Comparing the maser velocities with the velocities of the RMS sources, determined from ^{13}CO observations, we have identified 135 RMS-H_2O maser associations, which corresponds to a detection rate of ~27%. Taking into account the differences in sensitivity and source selection we find our detection rate is in general agreement with previously reported surveys.
Conclusions: We find similar detection rates for UCHII regions and MYSOs candidates, suggesting that the conditions needed for maser activity are equally likely in these two stages of the star formation process. Looking at the detection rate as a function of distance from the Galactic centre we find it significantly enhanced within the solar circle, peaking at ~37% between 6–7 kpc, which is consistent with previous surveys of UC HII regions, possibly indicating the presence of a high proportion of more luminous YSOs and HII regions.

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Hyperfine structure in the $J = 1{-}0$ transitions of DCO^+, DNC, and HN^{13}C: astronomical observations and quantum-chemical calculations

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Knowledge of the hyperfine structure of molecular lines is useful for estimating reliable column densities from observed emission, and essential for the derivation of kinematic information from line profiles.
Deuterium bearing molecules are especially useful in this regard, because they are good probes of the physical and chemical structure of molecular cloud cores on the verge of star formation. However, the necessary spectroscopic data are often missing, especially for molecules which are too unstable for laboratory study.
We have observed the ground-state ($J = 1 - 0$) rotational transitions of DCO^+, HN^{13}C and DNC with the IRAM 30m telescope toward the dark cloud LDN 1512 which has exceptionally narrow lines permitting hyperfine splitting to be resolved in part. The measured splittings of 50–300 kHz are used to derive nuclear quadrupole and spin-rotation parameters for these species. The measurements are supplemented by high-level quantum-chemical calculations using coupled-cluster techniques and large atomic-orbital basis sets.
We find $eQq = +151.12$ (400) kHz and $C_I = -1.12$ (43) kHz for DCO^+, $eQq = 272.5$ (51) kHz for HN^{13}C, and eQq(D) = 265.9(83) kHz and eQq(N) = 288.2 (71) kHz for DNC. The numbers for DNC are consistent with previous laboratory data, while our constants for DCO^+ are somewhat smaller than previous results based on astronomical data. For both DCO^+ and DNC, our results are more accurate than previous determinations. Our results are in good agreement with the corresponding best theoretical estimates, which amount to $eQq = 156.0$ kHz and $C_I = -0.69$ kHz for DCO^+, $eQq = 279.5$ kHz for HN^{13}C, and eQq(D) = 257.6 kHz and eQq(N) = 309.6 kHz for DNC. We also derive updated rotational constants for HN^{13}C: B=43545.6000(47) MHz and D=93.7(20) kHz.
The hyperfine splittings of the DCO^+, DNC and HN^{13}C $J = 1 - 0$ lines range over 0.47–1.28 km s^{-1}, which is comparable to typical line widths in pre-stellar cores and to systematic gas motions on ~1000 AU scales in protostellar cores. We present tabular information to allow inclusion of the hyperfine splitting in astronomical data interpretation.
The large differences in the ^{14}N quadrupole parameters of DNC and HN^{13}C have been traced to differences in the vibrational corrections caused by significant non-rigidity of these molecules, particularly along the bending coordinate.

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APEX-CHAMP+ high-J CO observations of low-mass young stellar objects: I The HH 46 envelope and outflow

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The spectacular outflow of HH 46/47 is driven by HH 46 IRS 1, an embedded Class I Young Stellar Object (YSO). Although much is known about this region from extensive optical and infrared observations, the properties of its protostellar envelope and molecular outflow are poorly constrained. Our aim is to characterize the size, mass, density and temperature profiles of the protostellar envelope of HH 46 IRS 1 and its surrounding cloud material as well as the effect the outflow has on its environment. The newly commisioned CHAMP$^+$ and LABOCA arrays on the APEX telescope, combined with lower frequency line receivers, are used to obtain a large ($5' \times 5'$, 0.6×0.6 pc) continuum map and smaller ($80'' \times 80''$, 36,000×36,000 AU) heterodyne maps in various isotopologues of CO and HCO$^+$. The high-J lines of CO (6–5 and 7–6) and its isotopologues together with [C I] 2–1, observed with CHAMP$^+$, are used to probe the warm molecular gas in the inner few hundred AU and in the outflowing gas. The data are interpreted with continuum and line radiative transfer models. Broad outflow wings are seen in CO low- and high-J lines at several positions, constraining the gas temperatures to a constant value of ~100 K along the red outflow axis and to ~60 K for the blue outflow. The derived outflow mass is of order 0.4–0.8 $M_\odot$, significantly higher than previously found. The bulk of the strong high-J CO line emission has a surprisingly narrow width, however, even at outflow positions. These lines cannot be fit by a passively heated model of the HH 46 IRS envelope. We propose that it originates from photon heating of the outflow cavity walls by ultraviolet photons originating in outflow shocks and the accretion disk boundary layers. At the position of the bow shock itself, the UV photons are energetic enough to dissociate CO. The envelope mass of ~5 $M_\odot$ is strongly concentrated towards HH 46 IRS with a density power law of −1.8. The fast mapping speed offered by CHAMP$^+$ allows the use of high-J CO lines and their isotopes to generate new insights into the physics of the interplay between the molecular outflow and protostellar envelope around low-mass protostars. The UV radiation inferred from the high-J CO and [C I] data will affect the chemistry of other species.

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APEX-CHAMP+ high-J CO observations of low-mass young stellar objects: II. Distribution and origin of warm molecular gas

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The origin and heating mechanisms of warm ($50< T <200$ K) molecular gas in low-mass young stellar objects (YSOs) are strongly debated. Both passive heating of the inner collapsing envelope by the protostellar luminosity as well as active heating by shocks and by UV associated with the outflows or accretion have been proposed. Most data so far have focussed on the colder gas component. We aim to characterize the warm gas within protosteller objects, and disentangle contributions from the (inner) envelope, bipolar outflows and the quiescent cloud. High-J CO maps (^{12}CO J=6–5 and 7–6) of the immediate surroundings (up to 10,000 AU) of eight low-mass YSOs are obtained with

the CHAMP$^+$ 650/850 GHz array receiver mounted on the APEX telescope. In addition, isotopologue observations of the ^{13}CO J =6–5 transition and [C I] $^3P_2 -^3 P_1$ line were taken. Strong quiescent narrow-line ^{12}CO 6–5 and 7–6 emission is seen toward all protostars. In the case of HH 46 and Ced 110 IRS 4, the on-source emission originates in material heated by UV photons scattered in the outflow cavity and not just by passive heating in the inner envelope. Warm quiescent gas is also present along the outflows, heated by UV photons from shocks. This is clearly evident in BHR 71 for which quiescent emission becomes stronger at more distant outflow positions. Shock-heated warm gas is only detected for Class 0 flows and the more massive Class I sources such as HH 46. Outflow temperatures, estimated from the CO 6–5 and 3–2 line wings, are ∼100 K, close to model predictions, with the exception of the L 1551 IRS 5 and IRAS 12496-7650, for which temperatures <50 K are found. APEX-CHAMP$^+$ is uniquely suited to directly probe the protostar's feedback on its accreting envelope gas in terms of heating, photodissociation, and outflow dispersal by mapping $\sim 1' \times 1'$ regions in high-J CO and [C I] lines. Photon-heating of the surrounding gas may prevent further collapse and limit stellar growth.

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http://www.cfa.harvard.edu/∼tvankemp/paper_files/tvk.hq.0908.3446.pdf

Simulations of Winds of Weak-Lined T Tauri Stars: The Magnetic Field Geometry and The Influence of the Wind on Giant Planet Migration

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By means of numerical simulations, we investigate magnetized stellar winds of pre-main-sequence stars. In particular we analyze under which circumstances these stars will present elongated magnetic features (e.g., helmet streamers, slingshot prominences, etc). We focus on weak-lined T Tauri stars, as the presence of the tenuous accretion disk is not expected to have strong influence on the structure of the stellar wind. We show that the plasma-β parameter (the ratio of thermal to magnetic energy densities) is a decisive factor in defining the magnetic configuration of the stellar wind. Using initial parameters within the observed range for these stars, we show that the coronal magnetic field configuration can vary between a dipole-like configuration and a configuration with strong collimated polar lines and closed streamers at the equator (multi-component configuration for the magnetic field). We show that elongated magnetic features will only be present if the plasma-β parameter at the coronal base is $\beta_0 \ll 1$. Using our self-consistent 3D MHD model, we estimate for these stellar winds the time-scale of planet migration due to drag forces exerted by the stellar wind on a hot-Jupiter. In contrast to the findings of Lovelace et al. (2008), who estimated such time-scales using the Weber & Davis model, our model suggests that the stellar wind of these multi-component coronae are not expected to have significant influence on hot-Jupiters migration. Further simulations are necessary to investigate this result under more intense surface magnetic field strengths (∼ 2-3 kG) and higher coronal base densities, as well as in a tilted stellar magnetosphere.

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Variable accretion in the embedded phase of star formation

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Motivated by the recent detection of a large number of embedded young stellar objects (YSOs) with mass accretion rates that are inconsistent with the predictions of the standard model of inside-out collapse (Shu 1977), we perform a series on numerical hydrodynamic simulations of the gravitational collapse of molecular cloud cores with various initial masses, rotation rates, and sizes. We focus on the early Class I stage of stellar evolution when circumstellar

disks are exposed to high rates of mass deposition from infalling envelopes. Our numerical modeling reproduces the large observed spread in accretion rates inferred for embedded YSOs in Perseus, Serpens, and Ophiuchus star forming regions by Enoch et al. (2009), yielding 37%–75% of objects with "sub-Shu" accretion rates $\dot{M} \leq 10^{-6}$ $M_{\odot}$ yr^{-1} and 1%–2% of objects with "super-Shu" accretion rates $\dot{M} > 10^{-5}$ $M_{\odot}$ yr^{-1}. Mass accretion rates in the Class I stage have a log-normal distribution, with its shape controlled by disk viscosity and disk temperature. The spread in $\dot{M}$ is greater in models with lower viscosity and smaller in models with higher viscosity and higher disk temperature, suggesting that gravitational instability may be a dominant cause of the observed diversity in $\dot{M}$ in embedded YSOs. Our modeling predicts a weak dependence between the mean mass accretion rates and stellar masses in the Class I stage, in sharp contrast to the corresponding steep dependence for evolved T Tauri stars and brown dwarfs.

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Herbig-Haro Objects in the Lupus I and III Molecular Clouds

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We performed a deep search for HH objects toward the Lupus I and III clouds, covering a sky area of ∼ 1 and ∼ 0.5 square degrees, respectively. In total 11 new HH objects, HH 981-991, are discovered. The HH objects both in Lupus I and in Lupus III tend to be concentrated in small areas. The HH objects detected in Lupus I are located in a region of radius 0.26 pc near the young star Sz 68. The abundance of HH objects shows that this region of the cloud is active in on-going star formation. HH objects in the Lup III cloud are concentrated in the central part of the cloud around the Herbig Ae/Be stars HR 5999 and 6000. HH 981 and 982 in Lupus I are probably driven by the young brown dwarf SSTc2d J154457.9-342340 which has a mass of 50 M_J. HH 990 and 991 in Lup III align well with the HH 600 jet emanating from the low-mass star Par-Lup3-4, and are probably excited by this low-mass star of spectral type M5. High proper motions for HH 228 W, E, and E2 are measured, which confirms that they are excited by the young star Th 28. In contrast, HH 78 exhibits no measurable proper motion in the time span of 18 years, indicating that HH 78 is unlikely part of the HH 228 flow. The HH objects in Lup I and III are generally weak in terms of brightness and dimension in comparison to HH objects we detected with the same technique in the R CrA and Cha I clouds. Through a comparison with the survey results from the Spitzer c2d program, we find that our optical survey is more sensitive, in terms of detection rate, than the Spitzer IRAC survey to high-velocity outflows in the Lup I and III clouds.

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The relation between ^{13}CO $J=2-1$ line width in molecular clouds and bolometric luminosity of associated IRAS sources

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Aims. We search for evidence of a relation between properties of young stellar objects (YSOs) and their parent molecular clouds to understand the initial conditions of high-mass star formation.
Methods. A sample of 135 sources was selected from the Infrared Astronomical Satellite (*IRAS*) Point Source Catalog, on the basis of their red color to enhance the possibility of discovering young sources. Using the Kölner Observatorium für SubMillimeter Astronomie (KOSMA) 3-m telescope, a single-point survey in ^{13}CO $J=2-1$ was carried out for the entire sample, and 14 sources were mapped further. Archival mid-infrared (MIR) data were compared with the ^{13}CO emissions to identify evolutionary stages of the sources. A ^{13}CO observed sample was assembled to investigate the correlation between ^{13}CO line width of the clouds and the luminosity of the associated YSOs.

Results. We identified 98 sources suitable for star formation analyses for which relevant parameters were calculated. We detected 18 cores from 14 mapped sources, which were identified with eight pre-UC H II regions and one UC H II region, two high-mass cores earlier than pre-UC H II phase, four possible star forming clusters, and three sourceless cores. By compiling a large (360 sources) ^{13}CO observed sample, a good correlation was found between the ^{13}CO line width of the clouds and the bolometric luminosity of the associated YSOs, which can be fitted as a power law, $\lg(\Delta V_{13}/\,\mathrm{km\,s^{-1}}) = (-0.023 \pm 0.044) + (0.135 \pm 0.012)\lg(\mathrm{L_{bol}/L_\odot})$. Results show that luminous ($> 10^3\,L_\odot$) YSOs tend to be associated with both more massive and more turbulent ($\Delta V_{13} > 2\,\mathrm{km\,s^{-1}}$) molecular cloud structures.

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The Lifetime of Protoplanetary Disks in a Low-Metallicity Environment

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The extreme outer Galaxy (EOG), the region with a Galactic radius of more than 18 kpc, is known to have very low metallicity, about one-tenth that of the solar neighborhood. We obtained deep near-infrared (NIR) images of two very young (∼0.5 Myr) star-forming clusters that are one of the most distant embedded clusters in the EOG. We find that in both clusters the fraction of stars with NIR excess, which originates from the circumstellar dust disk at radii of ≤0.1 AU, is significantly lower than those in the solar neighborhood. Our results suggest that most stars forming in the low-metallicity environment experience disk dispersal at an earlier stage (<1 Myr) than those forming in the solar metallicity environment (as much as ∼5–6 Myr). Such rapid disk dispersal may make the formation of planets difficult, and the shorter disk lifetime with lower metallicity could contribute to the strong metallicity dependence of the well-known "planet-metallicity correlation", which states the probability of a star hosting a planet increases steeply with stellar metallicity. The reason for the rapid disk dispersal could be increase of the mass accretion rate and/or the effective far-ultraviolet photoevaporation due to the low extinction; however, another unknown mechanism for the EOG environment could be contributing significantly. The reason for the rapid disk dispersal could be increase of the mass accretion rate and/or effective far ultraviolet photoevaporation.

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Explosive Disintegration of a Massive Young Stellar System in Orion

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Young massive stars in the center of crowded star clusters are expected to undergo close dynamical encounters that could lead to energetic, explosive events. However, there has so far never been clear observational evidence of such a remarkable phenomenon. We here report new interferometric observations that indicate the well known enigmatic wide-angle outflow located in the Orion BN/KL star-forming region to have been produced by such a violent explosion during the disruption of a massive young stellar system, and that this was caused by a close dynamical interaction about 500 years ago. This outflow thus belongs to a totally different family of molecular flows which is not related to the classical bipolar flows that are generated by stars during their formation process. Our molecular data allow us to create a 3D view of the debris flow and to link this directly to the well known Orion H_2 "fingers" farther out.

The Astrophysical Journal Letters

http://arxiv.org/abs/0907.3945

The 3D movie can be found in: ftp://ftp.mpifr-bonn.mpg.de/outgoing/lzapata/movie.gif

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Abstracts of recently accepted major reviews

Complex Organic Interstellar Molecules

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Of the over 150 different molecular species detected in the interstellar and circumstellar media, approximately 50 contain six or more atoms. These molecules, labeled "complex" by astronomers if not by chemists, all contain the element carbon and so can be called "organic". In the interstellar medium, complex molecules are detected in the denser sources only. Although with one exception, complex molecules have only been detected in the gas phase, there is strong evidence that they can be formed in ice mantles on interstellar grains. The nature of the gaseous complex species depends dramatically on the source where they are found: in cold dense regions they tend to be unsaturated (hydrogen-poor) and exotic, while in young stellar objects, they tend to be quite saturated (hydrogen-rich) and terrestrial in nature. Based on both their spectra and chemistry, complex molecules are excellent probes of the physical conditions and history of the sources where they reside. Because they are detected in young stellar objects, complex molecules are expected to be common ingredients for new planetary systems. In this review, we discuss both the observation and chemistry of complex molecules in assorted interstellar regions in the Milky Way.

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http://arjournals.annualreviews.org/eprint/vgpsNwpd4nYa99xjMNyt/full/10.1146/annurev-astro-082708-101654.

Astrochemistry in dense protostellar and protoplanetary environments

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Dense molecular clouds contain a remarkably rich chemistry, as revealed by combined submillimeter and infrared observations. Simple and complex (organic) gases, polycyclic aromatic hydrocarbons, ices and silicates have been unambiguously detected in both low- and high-mass star forming regions. During star- and planet formation, these molecules undergo large abundance changes, with most of the heavy species frozen out as icy mantles on grains in the cold pre-stellar phase. As the protostars heat up their immediate surroundings, the warming and evaporation of the ices triggers the formation of more complex molecules, perhaps even of pre-biotic origin. Water, a key ingredient in the chemistry of life, is boosted in abundance in hot gas. Some of these molecules enter the protoplanetary disk where they are exposed to UV radiation or X-rays and modified further. The enhanced resolution and sensitivity of ALMA, Herschel, SOFIA, JWST and ELTs across the full range of wavelengths from centimeters to micrometers will be essential to trace this lifecycle of gas and dust from clouds to planets. The continued need for basic molecular data on gaseous and solid-state material coupled with powerful radiative transfer tools is emphasized to reap the full scientific benefits from these new facilities.

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www.strw.leidenuniv.nl/~ewine/e-prints/dishoeck_tucson07.pdf

New Jobs

Infrared Astronomer: Star and Planet Formation Research

The Institute for Astronomy at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) is establishing a new infrared instrumentation laboratory with a scientific focus on star and planet formation research. Current projects include development of high contrast imaging systems and integral field spectrographs from 1-5 microns for existing large telescopes, as well as the next generation ELTs.

International applications are invited for positions ranging from Postdoctoral Fellow to Senior Research Scientist capable of directing the lab. Salary will be commensurate with experience (CHF 80'000-120'000) with junior appointments for a minimum of two years, and up to six+ years for senior candidates. Successful applicants will have the opportunity to work with students and access to the resources of the Star and Planet Formation Research Group led by Prof. Michael R. Meyer. Switzerland is a member of ESO and ESA, and successful applicants will have full access to their facilities, as well as data from ongoing programs utilizing the Spitzer Space Telescope, HST, the VLT, and other telescopes.

Applications should consist of a CV, past research and instrumentation experience, and proposed future activities (combined length not to exceed 12 pages). A separate publication list should be attached. These materials (as a single pdf file) as well as three letters of reference (directly from the referees) should be sent via email to chiesinm@phys.ethz.ch. Review of applications will begin immediately and continue until December 31, 2009 or the position is filled. More information can be found through the Institute for Astronomy, ETH website: http://www.astro.phys.ethz.ch/

Postdoctoral Research Position in Radiative Processes and Starburst Galaxies, University of Kentucky

Applications are invited for a postdoctoral research position in theoretical astrophysics to work with Prof. Moshe Elitzur at the University of Kentucky, Lexington, KY, USA. The start date is around September 2010, although an earlier start is possible. Interest in radiative processes and starburst galaxies is advantageous. The successful applicant will be able to join the science team of CanariCam, the mid-IR imager on the 10.4 m GTC telescope. Applicants should send curriculum vita, bibliography and a statement of research interests by e-mail to moshe@pa.uky.edu and arrange for three letters of recommendation to be sent the same way. The initial appointment is for one year, with an expected extension for another year. The review of applications will start at the end of December, and will be continued until the position is filled.

Positions in the field of extra-solar planets

The Centro de Astrofisica da Universidade do Porto (CAUP) opens a call for:

- 2 Advanced Post-doctoral Researchers (for an initial period of 2 years, possibly renewed up to 5 years)

- 1 Junior Post-doctoral Researcher (for a period of 1 year)

- 1 PhD student (4 years)

The positions are open in the field of extra-solar planets, and are to be started from the 1st of January 2010.

The yearly income of the Advanced Pos-Doctoral positions is above 24 500 euros. The income of the Junior Pos-Doc position is near 19 000 euro. The PhD fellowship has an yearly income of nearly 12 000 euros. All the above values are tax free. The project further includes funds for traveling (conferences, collaborations, observing missions).

The successful candidates are expected to pursue research in the following fields:

- Astrophysical limitations to the detection of Earth like planets (including stellar activity, oscillations, and granulation)

- Spectroscopic analysis of stars with planetary systems (foccusing on M-dwarfs and fast rotating FGK dwarfs)

- Extra-solar planet searches (in particular using radial-velocity and transit techniques)

The researchers will be included in the team on "Origin and Evolution of Stars and Planets" at CAUP.

The above mentioned research is to be seen in the context of the participation in the project of the ESPRESSO@VLT instrument (http://espresso.astro.up.pt), a new high resolution ultra stable spectrograph for the VLT.

For more details please go to:

http://www.astro.up.pt/caup/index.php?WID=141Lang=ukCID=1ID=51&Lang=uk&CID=1&ID=51

The two Advanced Post-doctoral Researchers as well as the PhD student positions are given in the context of the Starting Grant "EXtra-solar planets and stellar astrophysics: towards the detection of Other Earths" funded by the European Community/European Research Council under the FP7 Ideas programme.

The Junior Post-Doctoral researcher position is given in the context of grant PTDC/CTE-AST/098528/2008 funded by the Fundacao para a Ciencia e a Tecnologia (FCT, Portugal).

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