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Abstracts of recently accepted papers

Ambipolar Diffusion in Molecular Cloud Cores and the Gravomagneto Catastrophe

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This paper re-examines the problem of ambipolar diffusion as a mechanism for the production and runaway evolution of centrally condensed molecular cloud cores, a process that has been termed the gravomagneto catastrophe. Our calculation applies in the geometric limit of a highly flattened core and allows for a semi-analytic treatment of the full problem, although physical fixes are required to resolve a poor representation of the central region. A noteworthy feature of the overall formulation is that the solutions for the ambipolar diffusion portion of the evolution for negative times ($t < 0$) match smoothly onto the collapse solutions for positive times ($t > 0$). The treatment shows that the resulting cores display non-zero, but sub-magnetosonic, inward velocities at the end of the diffusion epoch, in agreement with current observations. Another important result is the derivation of an analytic relationship between the dimensionless mass to flux ratio $\lambda_0 \equiv f_0^{-1}$ of the central regions produced by runaway core condensation and the dimensionless measure of the rate of ambipolar diffusion ϵ. In conjunction with previous work showing that ambipolar diffusion takes place more quickly in the presence of turbulent fluctuations, i.e., that the effective value of ϵ can be enhanced by turbulence, the resultant theory provides a viable working hypothesis for the formation of isolated molecular-cloud cores and their subsequent collapse to form stars and planetary systems.

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Orbital Instabilities in a Triaxial Cusp Potential

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This paper constructs an analytic form for a triaxial potential that describes the dynamics of a wide variety of astrophysical systems, including the inner portions of dark matter halos, the central regions of galactic bulges, and young embedded star clusters. Specifically, this potential results from a density profile of the form $\rho(m) \propto m^{-1}$, where the radial coordinate is generalized to triaxial form so that $m^2 = x^2/a^2 + y^2/b^2 + z^2/c^2$. Using the resulting analytic form of the potential, and the corresponding force laws, we construct orbit solutions and show that a robust orbit instability exists in these systems. For orbits initially confined to any of the three principal planes, the motion in the perpendicular direction can be unstable. We discuss the range of parameter space for which these orbits are unstable, find the growth rates and saturation levels of the instability, and develop a set of analytic model equations that elucidate the essential physics of the instability mechanism. This orbit instability has a large number of astrophysical implications and applications, including understanding the formation of dark matter halos, the structure of galactic bulges, the survival of tidal streams, and the early evolution of embedded star clusters.

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Multiplicity Among Young Brown Dwarfs and Very Low Mass Stars

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Characterizing multiplicity in the very low mass (VLM) domain is a topic of much current interest and fundamental importance. Here we report on a near-infrared adaptive optics imaging survey of 31 young brown dwarfs and VLM stars, 28 of which are in the Chamaeleon I star-forming region, using the ESO Very Large Telescope. Our survey is sensitive enough to detect equal mass binaries down to separations of 0.04–0.07″ (∼6–10 AU at 160 pc) and, typically, companions with mass ratios ($q = m_2/m_1$) as low as 0.2 outside of 0.2″ (∼30 AU). We resolve the suspected 0.16″ (∼26 AU) binary ChaHα 2 and present two new binaries, Hn 13 and CHXR 15, with separations of 0.13″ (∼ 20 AU) and 0.30″ (∼ 50 AU) respectively; the latter system is one of the widest VLM systems discovered to date. We do not find companions around the majority of our targets giving an overall binary frequency of 11^{+9}_{-6}%, thus confirming the trend for a lower binary frequency with decreasing mass. By combining our work with previous surveys of VLM objects (VLMOs) in other star forming regions, we arrive at the largest sample of young VLMOs (72) with high angular resolution imaging to date. Its multiplicity fraction is in statistical agreement with that for VLMOs in the field. In addition we note that many field stellar binaries with lower binding energies and/or wider cross sections have survived dynamical evolution and that statistical models suggest tidal disruption by passing stars is unlikely to affect the binary properties of our systems. Thus, we argue that there is no significant evolution of multiplicity with age among brown dwarfs and VLM stars in OB and T associations between a few Myr to several Gyr. Instead, the observations to date suggest that VLM objects are either less likely to be born in fragile multiple systems than solar mass stars or such systems are disrupted very early (within the first couple of Myr).

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The circumbinary disk of HD 98800 B: Evidence for disk warping

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The quadruple young stellar system HD 98800 consists of two spectroscopic binary pairs with a circumbinary disk around the B component. Recent work by Boden and collaborators using infrared interferometry and radial velocity data resulted in a determination of the physical orbit for HD 98800 B. We use the resulting inclination of the binary and the measured extinction toward the B component stars to constrain the distribution of circumbinary material. Although a standard optically and geometrically thick disk model can reproduce the spectral energy distribution, it can not account for the observed extinction if the binary and the disk are co-planar. We next constructed a dynamical

model to investigate the influence of the A component, which is not in the Ba-Bb orbital plane, on the B disk. We find that these interactions have a substantial impact on the inclination of the B circumbinary disk with respect to the Ba-Bb orbital plane. The resulting warp would be sufficient to place material into the line of sight and the non-coplanar disk orientation may also cause the upper layers of the disk to intersect the line of sight if the disk is geometrically thick. These simulations also support that the dynamics of the Ba-Bb orbit clear the inner region to a radius of 3 AU. We then discuss whether the somewhat unusual properties of the HD 98800 B disk are consistent with material remnant from the star formation process or with more recent creation by collisions from larger bodies.

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Impact of the new solar abundances on the calibration of the PMS binary system RS Chamaeleontis

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Context. In a recent work, we tried to obtain a calibration of the two components of the pre-main sequence binary system RS Cha by means of theoretical stellar models. We found that the only way to reproduce the observational parameters of RS Cha with standard stellar models is to decrease the initial abundances of carbon and nitrogen derived from the GN93 solar mixture of heavy elements by a few tenths of dex.

Aims. In this work, we aim to reproduce the observational properties of the RS Cha stars with stellar evolution models based on the new AGS05 solar mixture recently derived from a three-dimensional solar model atmosphere. The AGS05 mixture is depleted in carbon, nitrogen and oxygen with respect to the GN93 mixture.

Methods. We calculated new stellar models of the RS Cha components using the AGS05 mixture and appropriate opacity tables. We sought models that simultaneously satisfy the observations of the two components (masses, radii, luminosities, effective temperatures and metallicity).

Results. We find that it is possible to reproduce the observational data of the RS Cha stars with AGS05 models based on standard input physics. From these models, the initial helium content of the system is $Y \sim 0.255$ and its age is $\sim 9.13 \pm 0.12$ Myr.

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Gravitational Collapse and Fragmentation of Molecular Cloud Cores with GADGET-2

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The collapse and fragmentation of molecular cloud cores is examined numerically with unprecedentedly high spatial resolutions, using the publicly released code GADGET-2. As templates for the model clouds we use the “standard isothermal test case” in the variant calculated by Burkert & Bodenheimer in 1993 and the centrally condensed, Gaussian cloud advanced by Boss in 1991. A barotropic equation of state is used to mimic the nonisothermal collapse. We investigate both the sensitivity of fragmentation to thermal retardation and the level of resolution needed by smoothed particle hydrodynamics (SPH) to achieve convergence to existing Jeans-resolved, finite-difference (FD) calculations. We find that working with 0.61.2 million particles, acceptably good convergence is achieved for the standard test model. In contrast, convergent results for the Gaussian-cloud model are achieved using from 5 to 10 million particles. If the isothermal collapse is prolonged to unrealistically high densities, the outcome of collapse for the Gaussian cloud

is a central adiabatic core surrounded by dense trailing spiral arms, which in turn may fragment in the late evolution. If, on the other hand, the barotropic equation of state is adjusted to mimic the rise of temperature predicted by radiative transfer calculations, the outcome of collapse is a protostellar binary core. At least, during the early phases of collapse leading to formation of the first protostellar core, thermal retardation not only favors fragmentation but also results in an increased number of fragments, for the Gaussian cloud.

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Equilibrium and stability of interstellar medium in its own gravitational field

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The statistical equilibrium of a heterogeneous self-gravitating layer of the interstellar medium is examined. Electrostatic fields and the different reactions to them by electrons and the ions of different elements are taken into account. In general, different, uncoupled temperatures are specified for the individual components of the interstellar medium. It is emphasized that some details of the structure of an equilibrium layer cannot be interpreted in terms of gravitation alone, despite the weakness of the electrostatic fields. A mixture of H II, He II, and electrons is examined as an important example. The asymptotic behavior of the total density and of the ratio of partial densities over large distances is found. A method for finding (in quadrature) these characteristics at any point of the medium is described.

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Multi-ionic Kinematical Study of the H II Region Sharpless 2-158

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The Sh 2-158 gas complex kinematics is analyzed using four lines from three different ions (Hα, [O III] λ5007, and [S II] $\lambda\lambda$6727, 6731) and the CO 10 line. The O^{++} and S^{+} data cubes were obtained using MOS FP at the CFHT, while the H^{+} data cube was obtained using FaNTOmM at the Observatoire du mont Mégantic. More than 200,000 spectra (S/N *ge* 5) were obtained. Maps of the radial velocity fields, the velocity line width field, and the electronic density field are discussed. All ionic mean radial velocities are blueshifted with respect to the molecular cloud (VLSR = -55.16 $\pm$ 0.02 km s^{-1}), more so as one goes from [S II] to Hα to [O III]. Two flows originating from the molecular cloud are identified. The encounter of the two flows, and possibly stellar winds, induces turbulence near the stars, causing larger line widths ($\approx$ 10 km s^{-1}) than elsewhere in the field. The mean [S II] line width is smaller than the mean [O III] line width, which is smaller than the mean Hα line width. Those differences between the ions are explained by the smaller [O III] Strömgren sphere compared to the Hα Strömgren sphere and the restriction of [S II] to a shell of gas near the molecular cloud. The most probable density value is 225 $\pm$ 25 cm^{-3}. The observations are mostly in agreement with the Champagne model. A geometrical model is proposed for Sh 2-158.

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INTEGRAL-ISGRI observations of the Cygnus OB2 region: Searching for hard X-ray point sources in a region containing several non-thermal emitting massive stars

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Aims. We analyze INTEGRAL-ISGRI data in order to probe the hard X-ray emission (above 20 keV) from point sources in the Cyg OB2 region and to investigate the putative non-thermal high-energy emission from early-type stars (Wolf-Rayet and O-type stars). Among the targets located in the field of view, we focus on the still unidentified EGRET source 3EG 2033+4118 that may be related to massive stars known to produce non-thermal emission in the radio domain, and on the wide colliding-wind binary WR 140.

Methods. Using a large set of data obtained with the IBIS-ISGRI imager onboard INTEGRAL, we run the OSA software package in order to find point sources in the fully coded field of view of the instrument.

Results. Our data do not allow the detection of a lower-energy counterpart of 3EG J2033+4118 nor of any other new point sources in the field of view, and we derive upper limits on the high-energy flux for a few targets: 3EG J2033+4118, TeV J2032+4130, WR 140, WR 146 and WR 147. The results are discussed in the context of the multiwavelength investigation of these objects.

Conclusions. The upper limits derived are valuable constraints for models aimed at understanding the acceleration of particles in non-thermal emitting massive stars, and of the still unidentified very-high gamma-ray source TeV J2032+4130.

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Energetic radiation and the sulfur chemistry of protostellar envelopes: Submillimeter interferometry of AFGL 2591

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The chemistry in the inner few thousand AU of accreting envelopes around young stellar objects is predicted to vary greatly with far-UV and X-ray irradiation by the central star.We search for molecular tracers of high-energy irradiation by the protostar in the hot inner envelope. The Submillimeter Array (SMA) has observed the high-mass star forming region AFGL 2591 in lines of CS, SO, HCN, HCN(ν_2=1), and $HC^{15}N$ with 0.6″ resolution at 350 GHz probing radial scales of 600-3500 AU for an assumed distance of 1 kpc. The SMA observations are compared with the predictions of a chemical model fitted to previous single-dish observations. The CS and SO main peaks are extended in space at the FWHM level, as predicted in the model assuming protostellar X-rays. However, the main peak sizes are found smaller than modeled by nearly a factor of 2. On the other hand, the lines of CS, HCN, and $HC^{15}N$, but not SO and HCN(ν_2=1), show pedestal emissions at radii $\lesssim$ 3500 AU that are not predicted. All lines except SO show a secondary peak within the approaching outflow cone. A dip or null in the visibilities caused by a sharp decrease in abundance with increasing radius is not observed in CS and only tentatively in SO. The emission of protostellar X-rays is supported by the good fit of the modeled SO and CS amplitude visibilities including an extended main peak in CS. The broad pedestals can be interpreted by far-UV irradiation in a spherically non-symmetric geometry, possibly comprising outflow walls on scales of 3500 – 7000 AU. The extended CS and SO main peaks suggest sulfur evaporation near the 100 K temperature radius. The effects of the corresponding abundance jumps may be reduced in visibility plots by smoothing due to inhomogeneity at the evaporation radius, varying by ±10% or more in different directions.

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The evolution of stars in the Taurus-Auriga T association

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In a recent study, individual parallaxes were determined for many stars of the Taurus-Auriga T association that are members of the same moving group. We use these new parallaxes to re-address the issue of the relationship between classical T Tauri stars (CTTSs) and weak-emission line T Tauri stars (WTTSs). With the available spectroscopic and photometric information for 72 individual stars or stellar systems among the Taurus-Auriga objects with known parallaxes, we derived reliable photospheric luminosities, mainly from the I_c magnitude of these objects. We then studied the mass and age distributions of the stellar sample, using pre-main sequence evolutionary models to determine the basic properties of the stellar sample. Statistical tests and Monte Carlo simulations were then applied to studying the properties of the two T Tauri subclasses. We find that the probability of CTTS and WTTS samples being drawn from the same parental age and mass distributions is low; CTTSs are, on average, younger than WTTSs. They are also less massive, but this is due to selection effects. The observed mass and age distributions of both T Tauri subclasses can be understood in the framework of a simple disk evolution model, assuming that the CTTSs evolve into WTTSs when their disks are fully accreted by the stars. According to this empirical model, the average disk lifetime in Taurus-Auriga is $4 \cdot 10^6 (M_*/M_\odot)^{0.75}$ yr.

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Photoionization Rates in Clumpy Molecular Clouds

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We present calculations of the continuum ultraviolet radiation field (91.2 nm $< \lambda <$ 550 nm) penetrating both uniform and clumpy (3D turbulent supersonic magnetohydrodynamic) starless molecular gas layers. We find that despite the self-shielding of clumps, pristine (i.e., unreddened) radiation penetrates deeply both the cloud's volume and its mass, resulting in a brighter and bluer intracloud radiation field compared to that in an equivalent uniform cloud. Motivated by these results, we construct and test a toy model ray-tracing scheme for the radiative transfer that fits the UV-visible spectral range with a three-parameter function. We calculate the photoionization rates, Λ, of the elements C, Na, Mg, Si, S, and Fe as functions of the visual extinction A_V along lines of sight. Typically, the difference in $\Lambda(A_V)$ between the clumpy and uniform clouds increases to orders of magnitude at even modest extinctions ($A_V \sim$ 2). Photoionization in the clumpy model extends 23 times deeper than in the uniform case, and it dominates cosmic-ray ionization throughout almost the entire volume. We encapsulate these average results in a parameterized form appropriate for when an approximate treatment of the effects of clumpiness is desired. However, the large point-to-point variance in this behavior suggests that uncertainties may arise when using mean values to model particular lines of sight in detail. Ideally, these new results would be used in conjunction with established results for homogeneous clouds in order to span a range of behavior that arises due to cloud inhomogeneities. We briefly explore the importance of the adopted dust properties, characterized by the selective extinction R_V and the scattering parameter g. We find that the UV field is considerably less sensitive to these dust properties in clumpy clouds, emphasizing the preeminence of geometry.

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H-atom bombardment of CO_2, HCOOH and CH_3CHO containing ices

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Context: Hydrogenation reactions are expected to be among the most important surface reactions on interstellar ices. However, solid state astrochemical laboratory data on reactions of H-atoms with common interstellar ice constituents are largely lacking.

Aims: The goal of our laboratory work is to determine whether and how carbon dioxide (CO_2), formic acid (HCOOH) and acetaldehyde (CH_3CHO) react with H-atoms in the solid state at low temperatures and to derive reaction rates and production yields.

Methods: Pure CO_2, HCOOH and CH_3CHO interstellar ice analogues are bombarded by H-atoms in an ultra-high vacuum experiment. The experimental conditions are varied systematically. The ices are monitored by reflection absorption infrared spectroscopy and the reaction products are detected in the gas phase through temperature programmed desorption. These techniques are used to determine the resulting destruction and formation yields as well as the corresponding reaction rates.

Results: Within the sensitivity of our set-up we conclude that H-atom bombardment of pure CO_2 and HCOOH ice does not result in detectable reaction products. The upper limits on the reaction rates are $\leq 7\times10^{-17}$ cm^2 s^{-1} which make it unlikely that these species play a major role in the formation of more complex organics in interstellar ices due to reactions with H-atoms. In contrast, CH_3CHO does react with H-atoms. At most 20% is hydrogenated to ethanol (C_2H_5OH) and a second reaction route leads to the break-up of the C–C bond to form solid state CH_4 ($\sim$20%) as well as H_2CO and CH_3OH (15–50%). The methane production yield is expected to be equal to the summed yield of H_2CO and CH_3OH and therefore CH_4 most likely evaporates partly after formation due to the high exothermicity of the reaction. The reaction rates for CH_3CHO destruction depend on ice temperature and not on ice thickness. The results are discussed in an astrophysical context.

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Dynamical Masses for Pre-Main Sequence Stars: A Preliminary Physical Orbit for V773 Tau A

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We report on interferometric and radial-velocity observations of the double-lined 51-d period binary (A) component of the quadruple pre-main sequence (PMS) system V773 Tau. With these observations we have estimated preliminary visual and physical orbits of the V773 Tau A subsystem. Among other parameters, our orbit model includes an inclination of 66.0 +/- 2.4 deg, and allows us to infer the component dynamical masses and system distance. In particular we find component masses of 1.54 +/- 0.14 and 1.332 +/- 0.097 Msun for the Aa (primary) and Ab (secondary) components respectively. Our modeling of the subsystem component spectral energy distributions finds temperatures and luminosities consistent with previous studies, and coupled with the component mass estimates allows for comparison with PMS stellar models in the intermediate-mass range. We compare V773 Tau A component properties with several popular solar-composition models for intermediate-mass PMS stars. All models predict masses consistent to within 2-sigma of the dynamically determined values, though some models predict values that are more

consistent than others.

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Can planetesimals left over from terrestrial planet formation produce the lunar Late Heavy Bombardment?

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The lunar Late Heavy Bombardment (LHB) defines a time between $\sim$ 3.8 to possibly 4.1 Gy ago when the Nectarian and early-Imbrium basins on the Moon with reasonably well-constrained ages were formed. Some have argued that these basins were produced by a terminal cataclysm that caused a spike in the inner Solar System impactor flux during this interval. Others have suggested the basins were formed by the tail end of a monotonically decreasing impactor population originally produced by planet formation processes in the inner Solar System. Here we investigate whether this so-called declining bombardment scenario of the LHB is consistent with constraints provided by planet formation models as well as the inferred ages of Nectaris, Serenitatis, Imbrium, and Orientale. We did this by modeling the collisional and dynamical evolution of the post-planet formation population (PPP) for a range of starting PPP masses. Using a Monte Carlo code, we computed the probability that the aforementioned basins were created at various times after the Moon-forming event approximately 4.54 Ga. Our results indicate that the likelihood that the declining bombardment scenario produced Nectaris, Serenitatis, Imbrium, and Orientale (or even just Imbrium and Orientale) at any of their predicted ages is extremely low and can be ruled out at the 3 confidence level, regardless of the PPP's starting mass. The reason is that collisional and dynamical evolution quickly depletes the PPP, leaving behind a paucity of large projectiles capable of producing the Moon's youngest basins between 3.84.1 Gy ago. If collisions are excluded from our model, we find that the PPP produces numerous South Pole-Aitken-like basins during the pre-Nectarian period. This is inconsistent with our understanding of lunar topography. Accordingly, our results lead us to conclude that the terminal cataclysm scenario is the only existing LHB paradigm at present that is both viable from a dynamical modeling perspective and consistent with existing constraints.

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A deeply embedded young protoplanetary disk around L1489 IRS observed by the submillimeter array

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Circumstellar disks are expected to form early in the process that leads to the formation of a young star, during the collapse of the dense molecular cloud core. It is currently not well understood at what stage of the collapse the disk is formed or how it subsequently evolves. We aim to identify whether an embedded Keplerian protoplanetary disk resides in the L1489 IRS system. Given the amount of envelope material still present, such a disk would respresent a very young example of a protoplanetary disk. Using the Submillimeter Array (SMA) we have observed the HCO^+ $J = 3$–2 line with a resolution of about $1''$. At this resolution a protoplanetary disk with a radius of a few hundred AUs should be detectable, if present. Radiative transfer tools are used to model the emission from both continuum and line data. We find that these data are consistent with theoretical models of a collapsing envelope and Keplerian circumstellar disk. Models reproducing both the SED and the interferometric continuum observations reveal that the disk is inclined by 40° which is significantly different to the surrounding envelope (74°). This misalignment of the angular momentum axes may be caused by a gradient within the angular momentum in the parental cloud or if L1489 IRS is a binary system rather than just a single star. In the latter case, future observations looking for variability at sub-arcsecond scales may be able to constrain these dynamical variations directly. However, if stars form

from turbulent cores, the accreting material will not have a constant angular momentum axis (although the average is well defined and conserved) in which case it is more likely to have a misalignment of the angular momentum axes of the disk and the envelope.

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Discovery of Par 1802 as a Low-Mass, Pre-Main-Sequence Eclipsing Binary in the Orion Star-Forming Region

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We report the discovery of a pre-main-sequence, low-mass, double-lined, spectroscopic, eclipsing binary in the Orion star-forming region. We present our observations including radial velocities derived from optical high-resolution spectroscopy, and present an orbit solution that permits the determination of precise empirical masses for both components of the system. We measure that Par 1802 is composed of two equal mass (0.39 ± 0.03, $0.40\pm0.03 M_{\odot}$) stars in a circular, 4.7 day orbit. There is strong evidence, such as the system exhibiting strong Li lines and a center-of-mass velocity consistent with cluster membership, that this system is a member of the Orion star-forming region and quite possibly the Orion Nebula Cluster, and therefore has an age of only a few million years. As there are currently only a few empirical mass and radius measurements for low-mass, PMS stars, this system presents an interesting test for the predictions of current theoretical models of pre-main sequence stellar evolution.

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Evolution of low-mass star and brown dwarf eclipsing binaries

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Context. We examine the evolution of low-mass star and brown dwarf eclipsing binaries. These objects are rapid rotators and are believed to shelter large magnetic fields.

Aims. We suggest that reduced convective efficiency, due to fast rotation and large field strengths, and/or to magnetic spot coverage of the radiating surface significantly affect their evolution, leading to a reduced heat flux and thus larger radii and cooler effective temperatures than for regular objects.

Methods. We have considered such processes in our evolutionary calculations, using a phenomenological approach.

Results. This yields mass-radius and effective temperature-radius relationships in agreement with the observations. We also reproduce the effective temperature ratio and the radii of the two components of the recently discovered puzzling eclipsing brown dwarf system.

Conclusions. These calculations show that fast rotation and/or magnetic activity may significantly affect the evolution of eclipsing binaries and that the mechanical and thermal properties of these objects depart from the ones of non-active low-mass objects. We find that, for internal field strengths compatible with the observed surface value of a few kiloGauss, convection can be severely inhibited. The onset of a central radiative zone for rapidly rotating active low-mass stars might thus occur below the usual $\sim 0.35\ M_{\odot}$ limit.

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The Spitzer c2d Survey of Large, Nearby, Interstellar Clouds. IV. Lupus Observed with MIPS

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We present maps of 7.78 deg^2 of the Lupus molecular cloud complex at 24, 70, and 160 μm. They were made with the Spitzer Space Telescope Multiband Imaging Photometer for Spitzer (MIPS) instrument as part of the Spitzer Legacy Program "From Molecular Cores to Planet-Forming Disks" (c2d). The maps cover three separate regions in Lupus, denoted I, III, and IV. We discuss the c2d pipeline and how our data processing differs from it. We compare source counts in the three regions with two other data sets and predicted star counts from the Wainscoat model. This comparison shows the contribution from background galaxies in Lupus I. We also create two color-magnitude diagrams using the 2MASS and MIPS data. From these results, we can identify background galaxies and distinguish them from probable young stellar objects. The sources in our catalogs are classified based on their spectral energy distribution (SED) from 2MASS and Spitzer wavelengths to create a sample of young stellar object candidates. From 2MASS data, we create extinction maps for each region and note a strong correspondence between the extinction and the 160 μm emission. The masses we derived in each Lupus cloud from our extinction maps are compared to masses estimated from ^{13}CO and C^{18}O and found to be similar to our extinction masses in some regions, but significantly different in others. Finally, based on our color-magnitude diagrams, we selected 12 of our reddest candidate young stellar objects for individual discussion. Five of the 12 appear to be newly discovered YSOs.

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The Dust and Gas Around β Pictoris

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We have obtained Spitzer IRS 5.535 μm spectroscopy of the debris disk around β Pictoris. In addition to the 10 μm silicate emission feature originally observed from the ground, we also detect the crystalline silicate emission bands at 28 and 33.5 μm. This is the first time that the silicate bands at wavelengths longer than 10 μm have ever been seen in the β Pictoris disk. The observed dust emission is well reproduced by a dust model consisting of fluffy cometary and crystalline olivine aggregates. We searched for line emission from molecular hydrogen and atomic [S I], Fe II, and Si II gas but detected none. We place a 3 σ upper limit of < 17 $M_\oplus$ on the H_2 S(1) gas mass, assuming an excitation temperature of $T_{ex} = 100$ K. This suggests that there is less gas in this system than is required to form the envelope of Jupiter. We hypothesize that some of the atomic Na I gas observed in Keplerian rotation around β Pictoris may be produced by photon-stimulated desorption from circumstellar dust grains.

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VLT/NACO adaptive optics imaging of GSS 30 IRS1: a protostellar binary system?

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We present high-resolution near-infrared images of the low-mass Class I young stellar object GSS 30 IRS1. The data were retrieved from the ESO archive and acquired in the HK_sL'-bands with the adaptive optics system NACO at the ESO *Very Large Telescope*. We discover two separate components in GSS 30 IRS1. The angular separation between the two components is ~ 0.15 arcsec, corresponding to a projected linear separation of 24 AU at a distance of 160 pc. The brightness contrasts between the two components are ~ 1.4 mag at H band, 1.5 mag at K_s band, and 2.1 mag at L' band. The two components detected in GSS 30 IRS1 could represent two scattered light structures related to an outflow-disk complex or two young stellar objects embedded in a common disk. Here we discuss these two possibilities, as well as the CO ro-vibrational emission from GSS 30 IRS1.

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The Relationship between the Optical Depth of the 9.7 μm Silicate Absorption Feature and Infrared Differential Extinction in Dense Clouds

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We have examined the relationship between the optical depth of the 9.7 μm silicate absorption feature ($\tau_{9.7}$) and the near-infrared color excess, E(J - K_s), in the Serpens, Taurus, IC 5146, Chameleon I, Barnard 59, and Barnard 68 dense clouds/cores. Our data set, based largely on Spitzer IRS spectra, spans E(J - K_s) = 0.310 mag (corresponding to visual extinction between about 2 and 60 mag). All lines of sight show the 9.7 μm silicate feature. Unlike in the diffuse ISM where a tight linear correlation between the 9.7 μm silicate feature optical depth and the extinction (A_V) is observed, we find that the silicate feature in dense clouds does not show a monotonic increase with extinction. Thus, in dense clouds, $\tau_{9.7}$ is not a good measure of total dust column density. With few exceptions, the measured $\tau_{9.7}$ values fall well below the diffuse ISM correlation line for E(J - K_s) > 2 mag ($A_V > 12$ mag). Grain growth via coagulation is a likely cause of this effect.

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The Spitzer c2d Survey of Weak-Line T Tauri Stars. II. New Constraints on the Timescale for Planet Building

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One of the central goals of the Spitzer Legacy Project "From Cores to Disks" (c2d) is to determine the frequency of circumstellar disks around weak-line T Tauri stars (WTTSs) and to study the properties and evolutionary status of these disks. Here we present a census of disks for a sample of over 230 WTTSs located in the c2d IRAC and MIPS maps of the Ophiuchus, Lupus, and Perseus Molecular Clouds. We find that $\sim$ 20% of the WTTSs in a magnitude-limited subsample have IR excesses at IRAC wavelengths. These disks frequencies are $\sim$ 36 times larger than that recently found for a sample of relatively isolated WTTSs located outside the highest extinction regions covered by the c2d maps. The disk fractions we find are more consistent with those obtained in recent Spitzer studies of WTTSs in young clusters such as IC 348 and Tr 37. According to their location in the H-R diagram, the WTTSs with excesses in our sample are among the younger part of the age distribution. Still, up to $\sim$ 50% of the apparently youngest stars in the sample show no evidence of IR excess, suggesting that the circumstellar disks of a sizable fraction of pre-main-sequence stars dissipate in a timescale of $\sim$ 1 Myr. We also find that none of the stars in our sample apparently older than $\sim$ 10 Myr have detectable circumstellar disks at wavelengths < 24 μm. The WTTS disks in our sample exhibit a wide range of properties (SED morphology, inner radius, $L_{disk}/L_{\star}$, etc.) that bridge the gaps observed between the CTTSs and the debris disk regimes.

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NICMOS Observations of Shocked H_2 in Orion

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HST NICMOS narrowband images of the shocked molecular hydrogen emission in OMC-1 are analyzed to reveal new information on the BN/KL outflow. The outstanding morphological feature of this region is the array of molecular hydrogen "fingers" emanating from the general vicinity of IRc2 and the presence of several Herbig-Haro objects. The NICMOS images appear to resolve individual shock fronts. This work is a more quantitative and detailed analysis of our data from a previous paper (Schultz et al. 1999).

Line strengths for the H_2 1–0 S(4) plus 2–1 S(6) lines at 1.89 μm are estimated from measurements with the Paschen α continuum filter F190N at 1.90 μm, and continuum measurements at 1.66 and 2.15 μm. We compare the observed H_2 line strengths and ratios of the 1.89 μm and 2.12 μm 1–0 S(1) lines with models for molecular cloud shock waves. Most of the data cannot be fit by J-shocks, but are well matched by C-shocks with shock velocities in the range of 20–45 $\mathrm{km\,s^{-1}}$ and preshock densities of $10^4 - 10^6$ $\mathrm{cm^{-3}}$, similiar to values obtained in larger beam studies which averaged over many shocks. There is also some evidence that shocks with higher densities have lower velocities.

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Magnetic fields in massive star forming regions

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We present the largest sample of high-mass star-forming regions observed using submillimetre imaging polarimetry. The data were taken using SCUBA in conjunction with the polarimeter on the JCMT in Hawaii. In total, 16 star forming regions were observed, although some of these contain multiple cores. The polarimetry implies a variety of magnetic field morphologies, with some very ordered fields. We see a decrease in polarisation percentage for 7 of the cores. The magnetic field strengths estimated for 14 of the cores, using the corrected CF method, range from ¡0.1 mG to almost 6 mG. These magnetic fields are weaker on these large scales when compared to previous Zeeman measurements from maser emission, implying the role of the magnetic field in star formation increases in importance on smaller scales. Analysis of the alignment of the mean field direction and the outflow directions reveal no relation for the whole sample, although direct comparison of the polarimetry maps suggests good alignment (to at least one outflow direction per source) in 7 out of the 15 sources with outflows.

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Discovery of Gas Accretion Onto Stars in 13 Myr old h and χ Persei

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We report the discovery of accretion disks associated with $\sim$ 13 Myr-old intermediate/low-mass stars in h and χ Persei. Optical spectroscopy of $\sim$ 5000 stars in these clusters and a surrounding halo population reveal 32 A-K stars with H$_\alpha$ emission. Matching these stars with 2MASS and optical photometry yields 25 stars with the highest probability of cluster membership and W(H$_\alpha$) $\geq$ 5 Å. Sixteen of these sources have EW(H$_\alpha$)$\geq$ 10Å. The population of accreting sources is strongly spectral type dependent: H$_\alpha$ emission characteristic of accretion, especially strong accretion (EW(H$_\alpha$) $\geq$ 10Å), is much more prevalent around stars later than G0. Strong H$_\alpha$ emission from accretion is typically associated with redder K$_s$-[8] colors. The existence of accreting pre-main sequence stars in h and χ Persei implies that circumstellar gas in some systems, especially those with primaries later than G5 spectral type, can last longer than 10-15 Myr.

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X-Ray Observations of the Young Cluster NGC 2264

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We present results from an X-ray imaging survey of the young cluster NGC 2264, carried out with the European Photon Imaging Cameras (EPIC) on board the XMM-Newton spacecraft. The X-ray data are merged with extant optical and near-infrared photometry, spectral classifications, Hα emission strengths, and rotation periods to examine the interrelationships between coronal and chromospheric activity, rotation, stellar mass, and internal structure for a statistically significant sample of pre-main-sequence stars. A total of 300 distinct X-ray sources can be identified with optical or near-infrared counterparts. The sources are concentrated within three regions of the cluster: in the vicinity of S Mon, within the large emission/reflection nebulosity southwest of S Mon, and along the broad ridge of molecular gas that extends from the Cone Nebula to the NGC 2264 IRS 2 field. From the extinction-corrected color-magnitude diagram of the cluster, ages and masses for the optically identified X-ray sources are derived. A median age of $\sim$2.5 Myr and an apparent age dispersion of $\sim$5 Myr are suggested by pre-main-sequence evolutionary models. The X-ray luminosity of the detected sources appears well correlated with bolometric luminosity, although there is considerable scatter in the relationship. Stellar mass contributes significantly to this dispersion, while isochronal age and rotation do not. X-ray luminosity and mass are well correlated such that $L_X \propto (M/M_\odot)^{1.5}$, similar to the relationship found within the younger Orion Nebula Cluster. No strong evidence is found for a correlation between E_{H-K}, the near-infrared color excess, and the fractional X-ray luminosity, which suggests that optically thick dust disks have little direct influence on the observed X-ray activity levels. Among the X-ray-detected weak-line T Tauri stars, the fractional X-ray luminosity, L_X/L_{bol}, is moderately well correlated with the fractional H luminosity, $L_{H\alpha}/L_{bol}$, but only at the 2 σ level of significance. The cumulative distribution functions for the X-ray luminosities of the X-ray-detected classical and weak-line T Tauri stars within the cluster are comparable, assuming the demarcation between the two classes is at an Hα equivalent width of 10 Å. However, if the nondetections in X-rays for the entire sample of Hα emitters known within the cluster are taken into account, then the cumulative distribution functions of these two groups are clearly different, such that classical T Tauri stars are underdetected by at least a factor of 2 relative to the weak-line T Tauri stars. Examining a small subsample of X-ray-detected stars that are probable accretors based on the presence of strong Hα emission and near-infrared excess, we conclude that definitive nonaccretors are $\sim$1.6 times more X-ray luminous than their accreting counterparts. In agreement with earlier published findings for the Orion Nebula Cluster, we find a slight positive correlation (valid at the 2 σ confidence level) between L_X/L_{bol} and rotation period in NGC 2264. The lack of a strong anticorrelation between X-ray activity and rotation period in the stellar population of NGC 2264 suggests that either the deeply convective T Tauri stars are rotationally saturated or the physical mechanism responsible for generating magnetic fields in pre-main-sequence stars is distinct from the one that operates in evolved main-sequence stars.

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On the Distance and Molecular Environment of Westerlund 2 and HESS J1023-575

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The extended TeV gamma-ray source HESS J1023-575 is coincident with the massive, young stellar cluster Westerlund 2 (Wd2) and its surrounding H II region RCW 49. On the basis of an analysis of the CO emission and 21 cm absorption along the line of sight to Wd2, it is argued that this cluster, and by assumption the TeV source as well, must be associated with a giant molecular cloud in the far side of the Carina arm with a mass of 7.5 $\times 10^5$ $M_\odot$. Analysis of the spatial and velocity structure of the cloud reveals clear evidence of interaction with Wd2. The cloud's kinematic distance of 6.0 $\pm$ 1.0 kpc is shown to be consistent with distances inferred from both the radiusline width relation of molecular clouds and the foreground gas column derived from 230 X-ray sources in Wd2.

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Mass Distribution and Planet Formation in the Solar Nebula

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The surface density profile of the solar nebula protoplanetary disk is a fundamental, and largely unknown, input to all models of disk processes and disk evolution. Traditionally the surface density $\Sigma(r)$ is estimated by spreading out the augmented masses of the planets over the annuli in which the planets orbit today, the so-called "minimum-mass solar nebula". An implicit assumption of these models is that the planets completely accreted all planetesimals in their feeding zones. This assumption has not been tested, and indeed models of the growth of Uranus and Neptune fail to predict that these planets could grow to $\sim 10\,M_{\oplus}$ within the lifetime of the disk, even though this must have occurred for these planets to accrete H/He atmospheres. In this paper we adopt the starting positions of the planets in the 'Nice' model of planetary dynamics (Tsiganis et al. 2005, *Nature* **435**, 459-461.), which predicts that the solar system started in a much more compact configuration. We derive a surface density profile that is well approximated by the power law $\Sigma(r) = 343\,(f_{\rm p}/0.5)^{-1}\,(r/10\,{\rm AU})^{-2.168}\,{\rm g\,cm^{-2}}$, where $f_{\rm p}$ is the fraction of the solids mass in the form of planetesimals. We show that his profile is inconsistent with a steady-state accretion disk, but is consistent with a steady-state decretion disk that is being photoevaporated. We calculate the growth of planets in the context of this disk model and demonstrate for the first time that *all* of the giant planets can achieve their isolation masses and begin to accrete H/He atmospheres within the lifetime of the disk. The fit of our inferred $\Sigma(r)$ to the augmented masses of the planets is excellent, to within tens of percent, but only if Uranus and Neptune swtiched places early in the solar system's evolution, a possibility predicted by the Nice model.

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The SCUBA Legacy Catalogues: Submillimetre Continuum Objects Detected by SCUBA

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We present the SCUBA Legacy Catalogues, two comprehensive sets of continuum maps (and catalogues) using data at 850 μm and 450 μm of the various astronomical objects obtained with the Submillimetre Common User Bolometer Array (SCUBA). The Fundamental Map Dataset contains data only where superior atmospheric opacity calibration data were available. The Extended Map Dataset is comprised of data regardless of the quality of the opacity calibration. Each Dataset contains $1.2^{\circ} \times 1.2^{\circ}$ maps at locations where data existed in the JCMT archive, imaged using the matrix inversion method. The Fundamental Dataset is comprised of 1423 maps at 850 μm and 1357 maps at 450 μm. The Extended Dataset is comprised of 1547 maps at 850 μm. Neither Dataset includes high sensitivity, single chop SCUBA maps of "cosmological fields" nor solar system objects. Each Dataset was used to determine a respective Object Catalogue, consisting of objects identified within the respective 850 μm maps using an automated identification algorithm. The Fundamental and Extended Map Object Catalogues contain 5061 and 6118 objects respectively. Objects are named based on their respective J2000 position of peak 850 μm intensity. The Catalogues provide for each object the respective maximum 850 μm intensity, estimates of total 850 μm flux and size, and tentative identifications from the SIMBAD Database. Where possible, the Catalogues also provide for each object its maximum 450 μm intensity and total 450 μm flux, and flux ratios.

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http://www.cadc.hia.nrc.gc.ca/community/scubalegacy

Dust sedimentation in protoplanetary disks with polycyclic aromatic hydrocarbons

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Context. Dust sedimentation is known to affect the infrared spectra and images of disks. In particular the far-infrared emission may be reduced by strong sedimentation. However, dust grains of different sizes sediment to different depths in the disk. Spectral features of one species may thus be enhanced, while those of other species may be suppressed.

Aims. Polycyclic aromatic hydrocarbons (PAHs) are among the smallest "dust grains". We investigate how the presence of PAHs in protoplanetary disks affects the disk's spectral energy distribution (SED) and feature strengths when the thermal (large) grains are allowed to sediment.

Methods. We calculate the vertical distribution of dust grains for both the PAH "dust" and the thermal dust grains. We include vertical settling and vertical mixing via turbulence. The results are inserted into a Monte-Carlo radiative transfer code to compute the SEDs.

Results. For high turbulence the sedimentation barely affects the spectrum. For low turbulence, however, the PAHs still stay well-mixed in the disk's surface layer, while the 0.1 μm size grains sediment deep into the disk. This strongly enhances the PAH features relative to the continuum (by factors of 2 to 10), while the far-infrared flux is reduced. This predicts that sources with weak far-infrared flux have stronger PAH features, which is - at least among Herbig Ae stars - opposite to what is observed, suggesting that sedimentation is not the only factor responsible for the weak mid- to far-infrared excess in some disks. We speculate that coagulation might be a solution, reducing both the mid- to far-infrared flux and the PAH features.

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Comparing Star Formation on Large Scales in the c2d Legacy Clouds: Bolocam 1.1 mm Dust Continuum Surveys of Serpens, Perseus, and Ophiuchus

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We have undertaken an unprecedentedly large 1.1 mm continuum survey of three nearby star-forming clouds using Bolocam at the Caltech Submillimeter Observatory. We mapped the largest areas in each cloud at millimeter or submillimeter wavelengths to date: 7.5 deg^2 in Perseus (Enoch and coworkers), 10.8 deg^2 in Ophiuchus (Young and coworkers), and 1.5 deg^2 in Serpens with a resolution of 31$''$, detecting 122, 44, and 35 cores, respectively. Here we report on results of the Serpens survey and compare the three clouds. Average measured angular core sizes and their dependence on resolution suggest that many of the observed sources are consistent with power-law density profiles. Tests of the effects of cloud distance reveal that linear resolution strongly affects measured source sizes and densities, but not the shape of the mass distribution. Core mass distribution slopes in Perseus and Ophiuchus ($\alpha = 2.1 \pm 0.1$ and 2.1 ± 0.3) are consistent with recent measurements of the stellar IMF, whereas the Serpens distribution is flatter ($\alpha = 1.6 \pm 0.2$). We also compare the relative mass distribution shapes to predictions from turbulent fragmentation simulations. Dense cores constitute less than 10% of the total cloud mass in all three clouds, consistent with other measurements of low star formation efficiencies. Furthermore, most cores are found at high column densities; more than 75% of 1.1 mm cores are associated with $A_V \gtrsim 8$ mag in Perseus, 15 mag in Serpens, and 2023 mag in Ophiuchus.

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OH Masers in G11.904-0.141

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The massive star-forming region G11.904-0.141 is one of only 11 sources to show maser emission in the highly excited 13441 MHz transition of OH. VLBA observations of the 1665, 1667, 4765, and 13441 MHz transitions of OH toward G11.904-0.141 are presented. Masers are detected at 1665, 1667, and 4765 MHz, but the 13441 MHz masers are not detected. Consistent magnetic field strengths of approximately +3.5 mG are detected in the ground-state masers, in contrast with a possible -3.0 mG magnetic field previously detected at 13441 MHz. The variable 13441 MHz masers may be associated with an outflow.

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The fractional ionization in dark molecular clouds

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We have studied the mechanisms which govern the degree of ionization of the gas in molecular clouds and prestellar cores, with a view to interpreting the relative abundances of the carbon–chain species C_nH and their negative ions, C_nH^-. We followed the chemical evolution of a medium comprising gas and dust as it evolves towards its steady–state composition. Various assumptions were made concerning the grain size–distribution and the fraction of very small grains (in practice, PAH), as well as the cosmic ray ionization rate. Particular attention was paid to reactions which determine the fractional ionization of the gas and the charge of the grains. We found that the abundance ratio $n(C_6H^-)/n(C_6H)$ is determined essentially by the ratio of the free electron density to the density of atomic hydrogen. A model with a high fractional abundance of PAH and a low fractional abundance of electrons yields agreement to a factor of 2 with the value of the ratio C_6H^-:C_6H observed recently in TMC-1. However, the fractional abundances of the molecular ions HCO^+ and DCO^+ are then higher than observed. The best overall fit with the observations of TMC-1 is obtained when the cosmic ray ionization rate is reduced, together with the rate of removal of atomic hydrogen from the gas phase (owing to adsorption on to grains).

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The effect of type I migration on the formation of terrestrial planets in hot-Jupiter systems

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Context. Our previous models of a giant planet migrating through an inner protoplanet/planetesimal disk find that the giant shepherds a portion of the material it encounters into interior orbits, whilst scattering the rest into external orbits. Scattering tends to dominate, leaving behind abundant material that can accrete into terrestrial planets.

Aims. We add to the possible realism of our model by simulating type I migration forces which cause an inward drift, and strong eccentricity and inclination damping of protoplanetary bodies. This extra dissipation might be expected to enhance shepherding at the expense of scattering, possibly modifying our previous conclusions.

Methods. We employ an N-body code that is linked to a viscous gas disk algorithm capable of simulating: gas accretion onto the central star; gap formation in the vicinity of the giant planet; type II migration of the giant planet; type I migration of protoplanets; and the effect of gas drag on planetesimals. We use the code to re-run three scenarios from

a previous work where type I migration was not included.

Results. The additional dissipation introduced by type I migration enhances the inward shepherding of material but does not severely reduce scattering. We find that >50% of the solids disk material still survives the migration in scattered exterior orbits: most of it well placed to complete terrestrial planet formation at <3 AU. The shepherded portion of the disk accretes into hot-Earths, which survive in interior orbits for the duration of our simulations.

Conclusions. Water-rich terrestrial planets can form in the habitable zones of hot-Jupiter systems and hot-Earths and hot-Neptunes may also be present. These systems should be targets of future planet search missions.

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Coronae in the *Coronet*: A very deep X-ray look into a stellar nursery

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In order to study the X-ray properties of young stellar objects (YSOs), we analyze an exceptionally sensitive *Chandra* dataset of the *Coronet* cluster in the CrA star-forming region, achieving a limiting luminosity of $L_{\mathrm{X,min}} \sim 5 \times 10^{26}$ erg/sec for lightly absorbed sources. This dataset represents one of the most sensitive X-ray observations ever obtained of a star-forming region. The X-ray data are used to investigate the membership status of tentative members of the region, to derive plasma temperatures and X-ray luminosities of the YSOs, and to investigate variability on the timescale of several years. 46 of the 92 X-ray sources in the merged *Chandra* image can be identified with optical or near/mid-infrared counterparts. X-ray emission is detected from *all* of the previously known optically visible late-type (spectral types G to M) stellar cluster members, from five of the eight brown dwarf candidates, and from nine embedded objects ("protostars") with class 0, class I, or flat-spectrum SEDs in the field of view. While the Herbig Ae/Be stars TY CrA and R CrA, a close companion of the B9e star HD 176386, and the F0e star T CrA are detected, no X-ray emission is found from any of the Herbig-Haro (HH) objects or the protostellar cores without infrared source. We find indications for diffuse X-ray emission near R CrA / IRS 7. The observed X-ray properties of the *Coronet* YSOs are consistent with coronal activity; no soft spectral components hinting towards X-ray emission from accretion shocks were found. The X-ray emission of the AeBe stars TY CrA and HD 176386 originates probably from close late-type companions. The Ae star R Cra shows a peculiar X-ray spectrum and an extremely hot plasma temperature. Finally, we discuss the differences of the X-ray properties of YSOs in different evolutionary stages.

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Oligarchic planetesimal accretion and giant planet formation

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Aims. In the context of the core instability model, we present calculations of in situ giant planet formation. The oligarchic growth regime of solid protoplanets is the model adopted for the growth of the core. This growth regime for the core has not been considered before in full evolutionary calculations of this kind.

Methods. The full differential equations of giant planet formation were numerically solved with an adaptation of a Henyey-type code. The planetesimals accretion rate was coupled in a self-consistent way to the envelope's evolution.

Results. We performed several simulations for the formation of a Jupiter-like object by assuming various surface densities for the protoplanetary disc and two different sizes for the accreted planetesimals. We first focus our study on the atmospheric gas drag that the incoming planetesimals suffer. We find that this effect gives rise to a major

enhancement on the effective capture radius of the protoplanet, thus leading to an average timescale reduction of $\sim$ 30%-55% and ultimately to an increase by a factor of 2 of the final mass of solids accreted as compared to the situation in which drag effects are neglected. In addition, we also examine the importance of the size of accreted planetesimals on the whole formation process. With regard to this second point, we find that for a swarm of planetesimals having a radius of 10 km, the formation time is a factor 2 to 3 shorter than that of planetesimals of 100 km, the factor depending on the surface density of the nebula. Moreover, planetesimal size does not seem to have a significant impact on the final mass of the core.

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The effect of a planet on the dust distribution in a 3D protoplanetary disk

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Aims: We investigate the behaviour of dust in protoplanetary disks under the action of gas drag in the presence of a planet. Our goal is twofold: to determine the spatial distribution of dust depending on grain size and planet mass, and therefore to provide a framework for interpretation of coming observations and future studies of planetesimal growth. Method: We numerically model the evolution of dust in a protoplanetary disk using a two-fluid (gas + dust) Smoothed Particle Hydrodynamics (SPH) code, which is non-self-gravitating and locally isothermal. The code follows the three dimensional distribution of dust in a protoplanetary disk as it interacts with the gas via aerodynamic drag. In this work, we present the evolution of a minimum mass solar nebula (MMSN) disk comprising 1% dust by mass in the presence of an embedded planet. We run a series of simulations which vary the grain size and planetary mass to see how they affect the resulting disk structure. Results: We find that gap formation is much more rapid and striking in the dust layer than in the gaseous disk and that a system with a given stellar, disk and planetary mass will have a completely different appearance depending on the grain size. For low mass planets in our MMSN disk, a gap can open in the dust disk while not in the gas disk. We also note that dust accumulates at the external edge of the planetary gap and speculate that the presence of a planet in the disk may enhance the formation of a second planet by facilitating the growth of planetesimals in this high density region.

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Physical Characteristics of a Dark Cloud in an Early Stage of Star Formation toward NGC 7538: An Outer Galaxy Infrared Dark Cloud?

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In the inner parts of the Galaxy the Infrared Dark Clouds (IRDCs) are presently believed to be the progenitors of massive stars and star clusters. Many of them are predominantly devoid of active star formation and for now they represent the earliest observed stages of massive star formation. Their Outer Galaxy counterparts, if present, are not easily identified because of a low or absent mid-IR background. We characterize the ambient conditions by determining physical parameters in the Outer Galaxy IRDC candidate G111.80+0.58, a relatively quiescent molecular core complex in the vicinity of active star forming regions such as NGC 7538 and S159. We conduct molecular line observations on a number of dense cores in G111.80+0.58. We analyze the data in terms of excitation temperature, column and volume density, mass and stability. The temperatures we find ($15-20$ K) are higher than expected from only cosmic ray heating, but are comparable to those found in massive cores, such as IRDCs. Star forming activity could be present in some cores, as indicated by the presence of warm gas (NH_3, ^{13}CO self-absorption) and Young Stellar Object candidates. The observed super-thermal line-widths are typical for star forming regions. The velocity dispersion is consistent with a turbulent energy cascade over the observed size scales of the complex. We do not find a correlation between the gas temperature and the line-width. The LTE masses we derive are much larger than the thermal Jeans mass. Therefore, fragmentation is expected and may have occurred already, in which case the observed lines represent the combined emission of multiple unresolved components. We conclude that G111.80+0.58 is a molecular core complex with bulk properties very similar to IRDCs in an early, but not pristine, star forming state. The individual cores are close to virial equilibrium and some contain sufficient material to form massive stars and star clusters. The ambient conditions suggest that turbulence is involved in supporting the cores against gravitational collapse, at least down to the observed sizes. Additional high resolution data are necessary to resolve and analyze the smaller scale properties.

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Spitzer-MIPS survey of the young stellar content in the Vela Molecular Cloud-D

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A new, unbiased Spitzer-MIPS imaging survey (~ 1.8 square degrees) of the young stellar content of the Vela Molecular Cloud-D is presented. The survey is complete down to 5 mJy and 250 mJy at 24 μm and 70 μm, respectively. A total of 849 sources are detected at 24 μm and 52 of them also have a 70 μm counterpart. The VMR-D region is one that we have already partially mapped in dust and gas millimeter emission, and we discuss the correlation between the Spitzer compact sources and the mm contours. About half of the 24 μm sources are located inside the region delimited by the $^{12}CO(1\text{-}0)$ contours, corresponding to only one third of the full area mapped with MIPS. Therefore the 24 μm source density increases by about 100% moving from outside to inside the CO contours. For the 70 μm sources, the corresponding density increase is four times. About 400 sources of these have a 2MASS counterpart, and we have used this to construct a K_s vs. K_s-[24] diagram and to identify the protostellar population inside the cloud.

We find an excess of Class I sources in VMR-D in comparison with other star forming regions. This result is reasonably biased by the sensitivity limits at 2.2 and 24 μm, or, alternatively, may reflect a very short lifetime ($\leq 10^6$ yr) of the protostellar content in this molecular cloud. The MIPS images have identified embedded cool objects in most of the previously identified starless cores in the region; in addition, there are 6 very young, possibly Class 0 objects identified. Finally we report finding of the driving sources for a set of five out of six very compact protostellar jets that had been previously discovered in near-infrared images of VMR-D.

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A survey of SiO 5→4 emission towards outflows from massive young stellar objects

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Results are presented of a survey of SiO 5→4 emission observed with the James Clerk Maxwell Telescope (JCMT) towards a sample of outflows from massive young stellar objects. The sample is drawn from a single-distance study by Ridge & Moore and allows the reasons that govern the detectability of SiO to be explored without the bias introduced by observing sources at different distances. This is the first such unbiased survey of SiO emission from massive outflows. In a sample of 12 sources, the 5→4 line was detected in 5, a detection rate of 42 per cent. This detection rate is higher than that found for a sample of low-luminosity outflow sources, although for sources of comparable luminosity, it is in good agreement with the results of a previous survey of high luminosity sources. For most of the detected sources, the 5→4 emission is compact or slightly extended along the direction of the outflow. NGC 6334I shows a clear bipolar flow in the 5→4 line. Additional data were obtained for W3-IRS5, AFGL 5142 and W75N for the 2→1 transition of SiO using the Berkeley-Illinois-Maryland Association (BIMA) millimetre interferometer. There is broad agreement between the appearance of the SiO emission in both lines, though there are some minor differences. The 2→1 emission in AFGL 5142 is resolved into two outflow lobes which are spatially coincident on the sky, in good agreement with previous observations. In general the SiO emission is clearly associated with the outflow. Simple analysis and radiative transfer modelling of the detected sources yield similar SiO column densities. The abundance of SiO is ~ 0.1–7.0×10^{-9}, and the H_2 number density is within a factor of two of $10^5\,\mathrm{cm}^{-3}$. However, the temperature is not constrained over the range 50–150 K. The primary indicator of SiO 5→4 detectability is the outflow velocity, i.e. the presence of SiO is an indicator of a high velocity outflow. This result is consistent with the existence of a critical shock velocity required to disrupt dust grains and subsequent SiO formation in post-shock gas. There is also weak evidence that higher luminosity sources and denser outflows are more likely to be detected.

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Quantitative optical and near-infrared spectroscopy of H2 towards HH91A

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Integral-field spectroscopy of molecular hydrogen in the optical wavelength region and complementary long-slit near-infrared spectroscopy are presented towards HH91A.The detection of some 200 H_2 lines arising from ro-vibrational levels up to v'=8 ranging between 7700A and 2.3 microns is reported. The emission arises from thermally excited gas where the bulk of the material is at 2750 K and where 1% is at 6000 K. The total column density of shocked gas is $N(H_2) = 10^{18}\ \mathrm{cm}^{-2}$. Non-thermal excitation scenarios such as UV-fluorescence do not contribute to the excitation of H_2 towards HH91A. The emission is explained in terms of a slow non-dissociative J-shock which propagates into a low-density medium which has been swept-up by previous episodes of outflows which have occurred in the evolved HH90/91 complex.

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Observation of enhanced X-ray emission from the CTTS AA Tau during one transit of an accretion funnel

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Context. Classical T Tauri stars are young solar-type stars accreting material from their circumstellar disks. Thanks to a favorable inclination of the system, the classical T Tauri star AA Tau exhibits periodic optical eclipses as the warped inner disk edge occults the stellar photosphere.
Aims. We intend to observe the X-ray and UV emission of AA Tau during the optical eclipses with the aim of localizing these emitting regions on the star.
Methods. AA Tau was observed for about 5 h per *XMM-Newton* orbit (2 days) over 8 successive orbits, which covers two optical eclipse periods (8.22 days). The *XMM-Newton* optical/UV monitor simultaneously provided UV photometry (UVW2 filter at 206 nm) with a ∼15 min sampling rate. Some V-band photometry was also obtained from the ground during this period in order to determine the dates of the eclipses.
Results. Two X-ray and UV measurements were secured close to the center of the eclipse ($\Delta V \sim 1.5$ mag). The UV flux is the highest just before the eclipse starts and the lowest towards the end of it. UV flux variations amount to a few 0.1 mag on a timescale of a few hours and up to 1 mag on a timescale of a week, none of which are correlated with the X-ray flux. We model it with a weekly modulation (inner disk eclipse), plus a daily modulation, which suggests a non-steady accretion, but needs a longer observation to be confirmed. No such eclipses are detected in X-rays. Within each 5 h-long observation, AA Tau has a nearly constant X-ray count rate. On a timescale of days to weeks, the X-ray flux varies by a factor of 2–8, except for one measurement where the X-ray count rate was nearly 50 times higher than the minimum observed level even though photoelectric absorption was the highest at this phase, and the plasma temperature reached 60 MK, i.e. a factor of 2–3 higher than in the other observations. This X-ray event, observed close to the center of the optical eclipse, is interpreted as an X-ray flare.
Conclusions. We explain the variable column density with the low-density accretion funnel flows blanketing the magnetosphere. The lack of X-ray eclipses indicates that X-ray emitting regions are located at high latitudes. Furthermore, the occurrence of a strong X-ray flare near the center of the optical eclipse suggests that the magnetically active areas are closely associated with the base of the high-density accretion funnel flow. We speculate that the impact of this free-falling accretion flow onto the strong magnetic field of the stellar corona may boost the X-ray emission.

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Spectropolarimetry of the Hα line in Herbig Ae/Be stars

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Using the HiVIS spectropolarimeter built for the Haleakala 3.7m AEOS telescope, we have obtained a large number of high precision spectropolarimetrc observations (284) of Herbig AeBe stars collected over 53 nights totaling more than 300 hours of observing. Our sample of five HAeBe stars: AB Aurigae, MWC480, MWC120, MWC158 and HD58647, all show systematic variations in the linear polarization amplitude and direction as a function of time and wavelength near the Hα line. In all our stars, the Hα line profiles show evidence of an intervening disk or outflowing wind, evidenced by strong emission with an absorptive component. The linear polarization varies by 0.2to 1.5% with the change typically centered in the absorptive part of the line profile. These observations are inconsistent with a simple disk-scattering model or a depolarization model which produce polarization changes centered on the emmissive core. We speculate that polarized absorption via optical pumping of the intervening gas may be the cause.

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Cooling, Gravity and Geometry: Flow-driven Massive Core Formation

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We study numerically the formation of molecular clouds in large-scale colliding flows including self-gravity. The models emphasize the competition between the effects of gravity on global and local scales in an isolated cloud. Global gravity builds up large-scale filaments, while local gravity – triggered by a combination of strong thermal and dynamical instabilities – causes cores to form. The dynamical instabilities give rise to a local focusing of the colliding flows, facilitating the rapid formation of massive protostellar cores of a few 100 $M_\odot$. The forming clouds do not reach an equilibrium state, though the motions within the clouds appear comparable to "virial". The self-similar core mass distributions derived from models with and without self-gravity indicate that the core mass distribution is set very early on during the cloud formation process, predominantly by a combination of thermal and dynamical instabilities rather than by self-gravity.

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Magnetic processes in a collapsing dense core. I Accretion and Ejection

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It is important for the star formation process to understand the collapse of a prestellar dense core. We investigate the effect of the magnetic field during the first collapse up to the formation of the first core, focusing particularly on the magnetic braking and the launching of outflows. We perform 3D AMR high resolution numerical simulations of a magnetically supercritical collapsing dense core using the RAMSES MHD code and develop semi-analytical models that we compare with the numerical results. We study in detail the various profiles within the envelope of the collapsing core for various magnetic field strengths. Even modest values of magnetic field strength modify the collapse significantly. This is largely due to the amplification of the radial and toroidal components of the magnetic field by the differential motions within the collapsing core. For a weak magnetic intensity corresponding to an initial mass-to-flux over critical mass-to-flux ratio, μ equals to 20, a centrifugally supported disk forms. The strong differential rotation triggers the growth of a slowly expanding magnetic tower. For a higher magnetic field strengths corresponding to $\mu = 2$, the collapse occurs primarily along the field lines, therefore delivering weaker angular momentum in the inner part whereas at the same time, strong magnetic braking occurs. As a consequence no centrifugally supported disk forms. An outflow is launched from the central thermally supported core. Detailed comparisons with existing analytical predictions indicate that it is magneto-centrifugally driven. For cores having a mass-to-flux over critical mass-to-flux radio $\mu < 5$, the magnetic field appears to have a significant impact. The collapsing envelope is denser and flatter than in the hydrodynamical case and no centrifugally supported disk forms. For values $\mu < 20$, the magnetic field drastically modifies the disk evolution. In a companion paper, the influence of the magnetic field on the dense core fragmentation is studied.

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High-Resolution Spectroscopy of Ne II Emission from TW Hya

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We present high-resolution echelle spectra of [Ne II] 12.81 micron emission from the classical T Tauri star (CTTS) TW Hya obtained with MICHELLE on Gemini North. The line is centered at the stellar radial velocity and has an intrinsic FWHM of 21 ± 4 km s^{-1}. The line width is broader than other narrow emission lines typically associated with the disk around TW Hya. If formed in a disk, the line broadening could result from turbulence in a warm disk atmosphere, Keplerian rotation at an average distance of 0.1 AU from the star, or a photoevaporative flow from the optically-thin region of the disk. We place upper limits on the [Ne II] emission flux from the CTTSs DP Tau and BP

Tau.

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Astrometry of Water Maser Sources in Nearby Molecular Clouds with VERA — II. SVS 13 in NGC 1333

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We report on the results of multi-epoch VLBI observations with VERA (VLBI Exploration of Radio Astrometry) of the 22 GHz H_2O masers associated with the young stellar object SVS 13 in the NGC 1333 region. We have carried out phase-referencing VLBI astrometry and measured an annual parallax of the maser features in SVS 13 of 4.25±0.32 mas, corresponding to the distance of 235±18 pc from the Sun. Our result is consistent with a photometric distance of 220 pc previously reported. Even though the maser features were detectable only for 6 months, the present results provide the distance to NGC 1333 with much higher accuracy than photometric methods. The absolute positions and proper motions have been derived, revealing that the H_2O masers with the LSR (local standard of rest) velocities of 7-8 km s^{-1} are most likely associated with VLA4A, which is a radio counterpart of SVS 13. The origin of the observed proper motions of the maser features are currently difficult to attribute to either the jet or the rotating circumstellar disk associated with VLA4A, which should be investigated through future high-resolution astrometric observations of VLA4A and other radio sources in NGC 1333.

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astroph 0709.1626

New H_2 Jets in Monoceros R2

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We are presenting a wide-field image of the Mon R2 star forming region obtained with WFCAM on UKIRT in the 2.12 μm filter centered on the H_2 1–0 S(1) emission line. We report the discovery of 15 new H_2 jets in Mon R2 and two in L 1646 and confirm most of these discoveries using archival Spitzer IRAC 4.5 μm and 8.0 μm images. We find that many of these protostellar jets are found in projection against the outflow cavities of the huge CO outflow in Mon R2, suggesting that the jets may be associated with an episode of star formation in Mon R2 triggered by this large, but now fossil, outflow. We also study the spatial distribution of small, localized reflection nebulae and find that these are distributed in the same way as photometrically identified Class I sources.

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Evidence for Accretion in the High-resolution X-ray Spectrum of the T Tauri Star System Hen 3-600

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We present high-resolution X-ray spectra of the multiple T Tauri star system Hen 3-600, obtained with the High Energy Transmission Grating Spectrograph on the Chandra X-ray Observatory. Two binary components were detected in the zeroth-order image. Hen 3-600-A, which has a large mid-infrared excess, is a 2-3 times fainter in X-rays than Hen 3-600-B, due to a large flare on B. The dispersed X-ray spectra of the two primary components overlap spatially; spectral analysis was performed on the combined system. Analysis of the individual spectra was limited to regions where the contributions of A and B can be disentangled. This analysis results in two lines of evidence indicating that the X-ray emission from Hen 3-600 is derived from accretion processes: line ratios of O VII indicate that the characteristic density of its X-ray-emitting plasma is large; a significant component of low-temperature plasma is present and is stronger in component A. These results are consistent with results obtained from X-ray gratings spectroscopy of more rapidly accreting systems. All of the signatures of Hen 3-600 that are potential diagnostics of accretion activity — X-ray emission, UV excess, H-alpha emission, and weak infrared excess — suggest that its components represent a transition phase between rapidly accreting, classical T Tauri stars and non-accreting, weak-lined T Tauri stars.

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Embedded Star Formation in the Eagle Nebula with Spitzer GLIMPSE

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We present new Spitzer photometry of the Eagle Nebula (M16, containing the optical cluster NGC 6611) combined with near-infrared photometry from 2MASS. We use dust radiative transfer models, mid-infrared and near-infrared color-color analysis, and mid-infrared spectral indices to analyze point-source spectral energy distributions, select candidate YSOs, and constrain their mass and evolutionary state. Comparison of the different protostellar selection methods shows that mid-infrared methods are consistent, but as has been known for some time, near-infraredonly analysis misses some young objects. We reveal more than 400 protostellar candidates, including one massive YSO that has not been previously highlighted. The YSO distribution supports a picture of distributed low-level star formation, with no strong evidence of triggered star formation in the "pillars." We confirm the youth of NGC 6611 by a large fraction of infrared excess sources and reveal a younger cluster of YSOs in the nearby molecular cloud. Analysis of the YSO clustering properties shows a possible imprint of the molecular cloud's Jeans length. Multiwavelength mid-IR imaging thus allows us to analyze the protostellar population, to measure the dust temperature and column density, and to relate these in a consistent picture of star formation in M16.

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The Monitor project: JW 380 a 0.26-, 0.15-M$_\odot$, pre-main-sequence eclipsing binary in the Orion nebula cluster

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We report the discovery of a low-mass (0.26 ± 0.02, 0.15 ± 0.01 $M_\odot$) pre-main-sequence (PMS) eclipsing binary (EB) with a 5.3 d orbital period. JW 380 was detected as part of a high-cadence time-resolved photometric survey (the Monitor project) using the 2.5-m Isaac Newton Telescope and Wide Field Camera for a survey of a single field in the Orion nebula cluster (ONC) region in V and i bands. The star is assigned a 99 per cent membership probability from proper motion measurements, and radial velocity observations indicate a systemic velocity within 1σ of that of the ONC. Modelling of the combined light and radial velocity curves of the system gave stellar radii of $1.19^{+0.04}_{-0.18}$ and $0.90^{+0.17}_{-0.03}$ $R_\odot$ for the primary and the secondary, with a significant third light contribution which is also visible as a third peak in the cross-correlation functions used to derive radial velocities. The masses and radii appear to be consistent with stellar models for 23 Myr age from several authors, within the present observational errors. These observations probe an important region of massradius parameter space, where there are currently only a handful of known PMS EB systems with precise measurements available in the literature.

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Using rotation rates to probe age spreads in the Orion Nebula Cluster

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The radii of young pre-main-sequence (PMS) stars in the Orion Nebula Cluster (ONC) have been estimated using their rotation periods and projected equatorial velocities. Stars at a given effective temperature have a spread in their geometrically estimated projected radii that is larger than can be accounted for with a coeval model, observational uncertainties and randomly oriented rotation axes. It is shown that the required dispersion in radius (a factor of 2–3 full width half maximum) can be modelled in terms of a spread in stellar ages larger than the median age of the cluster, although the detailed star formation history cannot be uniquely determined using present data. This technique is relatively free from systematic uncertainties (binarity, extinction, variability, distance) that have hampered previous studies of the ONC star formation history using the conventional Hertzsprung-Russell diagram. However, the current ONC rotational data are biased against low luminosity objects, so the deduced dispersions in radius and inferred age are probably underestimates. In particular, the ages of a tail of PMS stars that appear to be ≥ 10 Myr old in the Hertzsprung-Russell diagram cannot be verified with present data. If projected equatorial velocities were measured for these objects it could easily be checked whether their radii are correspondingly smaller than the bulk of the ONC population.

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Rapid planetesimal formation in turbulent circumstellar discs

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The initial stages of planet formation in circumstellar gas discs proceed via dust grains that collide and build up larger and larger bodies (Safronov 1969). How this process continues from metre-sized boulders to kilometre-scale planetesimals is a major unsolved problem (Dominik et al. 2007): boulders stick together poorly (Benz 2000), and spiral into the protostar in a few hundred orbits due to a head wind from the slower rotating gas (Weidenschilling 1977). Gravitational collapse of the solid component has been suggested to overcome this barrier (Safronov 1969; Goldreich & Ward 1973, Youdin & Shu 2002). Even low levels of turbulence, however, inhibit sedimentation of solids to a sufficiently dense midplane layer (Weidenschilling & Cuzzi 1993; Dominik et al. 2007), but turbulence must be present to explain observed gas accretion in protostellar discs (Hartmann 1998). Here we report the discovery of efficient gravitational collapse of boulders in locally overdense regions in the midplane. The boulders concentrate initially in transient high pressures in the turbulent gas (Johansen, Klahr, & Henning 2006), and these concentrations are augmented a further order of magnitude by a streaming instability (Youdin & Goodman 2005; Johansen, Henning, & Klahr 2006; Johansen & Youdin 2007) driven by the relative flow of gas and solids. We find that gravitationally bound clusters form with masses comparable to dwarf planets and containing a distribution of boulder sizes. Gravitational collapse happens much faster than radial drift, offering a possible path to planetesimal formation in accreting circumstellar discs.

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Numerical Simulations of HH 555

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We present 3D gasdynamic simulations of the Herbig Haro object HH 555. HH 555 is a bipolar jet emerging from the tip of an elephant trunk entering the Pelican Nebula from the adjacent molecular cloud. Both beams of HH 555 are curved away from the center of the H II region. This indicates that they are being deflected by a side-wind probably coming from a star located inside the nebula or by the expansion of the nebula itself. HH 555 is most likely an irradiated jet emerging from a highly embedded protostar, which has not yet been detected.

In our simulations we vary the incident photon flux, which in one of our models is equal to the flux coming from a star 1 pc away emitting 5×10^{48} ionizing (i. e., with energies above the H Lyman limit) photons per second. An external, plane-parallel flow (a "side-wind") is coming from the same direction as the photoionizing flux. We have made four simulations, decreasing the photon flux by a factor of 10 in each simulation. We discuss the properties of the flow and we compute Hα emission maps (integrated along lines of sight). We show that the level of the incident photon flux has an important influence on the shape and visibility of the jet. If the flux is very high, it causes a strong evaporation of the neutral clump, producing a photoevaporated wind traveling in the direction opposite to the incident flow. The interaction of the two flows creates a double shock "working surface" around the clump protecting it and the jet from the external flow. The jet only starts to curve when it penetrates through the working surface.

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Magnetohydronamic Evolution of HII Regions in Molecular Clouds: Simulation Methodology, Tests, and Uniform Media

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We present a method for simulating the evolution of HII regions driven by point sources of ionizing radiation in magnetohydrodynamic media, implemented in the three-dimensional Athena MHD code. We compare simulations using our algorithm to analytic solutions and show that the method passes rigorous tests of accuracy and convergence. The tests reveal several conditions that an ionizing radiation-hydrodynamic code must satisfy to reproduce analytic solutions. As a demonstration of our new method, we present the first three-dimensional, global simulation of an HII region expanding into a magnetized gas. The simulation shows that magnetic fields suppress sweeping up of gas perpendicular to magnetic field lines, leading to small density contrasts and extremely weak shocks at the leading edge of the HII region's expanding shell.

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c2d Spitzer IRS Spectra of Disks around T Tauri Stars. III. [Ne II], [Fe I], and H2 Gas-Phase Lines

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We present a survey of mid-infrared gas-phase lines toward a sample of 76 circumstellar disks around low mass pre-main sequence stars from the *Spitzer* "Cores to Disks" legacy program. We report the first detections of [Ne II] and [Fe I] toward classical T Tauri stars in $\sim 20\,\%$ respectively $\sim 9\,\%$ of our sources. The observed [Ne II] line fluxes and upper limits are consistent with [Ne II] excitation in an X-ray irradiated disk around stars with X-ray luminosities $L_{\rm X} = 10^{29} - 10^{31}\,{\rm erg\,s^{-1}}$. [Fe I] is detected at $\sim 10^{-5} - 10^{-4}\,L_\odot$, but no [S I] or [Fe II] is detected down to $\sim 10^{-6}\,L_\odot$. The [Fe I] detections indicate the presence of gas-rich disks with masses of $\geq 0.1 M_{\rm J}$. No H_2 0-0 S(0) and S(1) disk emission is detected, except for S(1) toward one source. These data give upper limits on the warm ($T \sim 100-200\,$K) gas mass of a few Jovian masses, consistent with recent T Tauri disk models which include gas heating by stellar radiation. Compact disk emission of hot ($T \geq 500\,$K) gas is observed through the H_2 0-0 S(2) and/or S(3) lines toward $\sim 8\,\%$ of our sources. The line fluxes are, however, higher by more than an order of magnitude than those predicted by recent disk models, even when X-ray and excess UV radiation are included. Similarly the [Ne II]/H_2 0-0 S(2) ratios for these sources are lower than predicted, consistent with the presence of an additional hot molecular gas component not included in current disk models. Oblique shocks of stellar winds interacting with the disk can explain many aspects of the hot gas emission, but are inconsistent with the non-detection of [S I] and [Fe II] lines.

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Molecular Line Observations of the Small Protostellar Group L1251B

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We present molecular line observations of L1251B, a small group of pre- and protostellar objects, and its immediate environment in the dense C18O core L1251E. These data are complementary to near-infrared, submillimeter and millimeter continuum observations reported by Lee et al. (2006, ApJ, 648, 491; Paper I). The single-dish data of L1251B described here show very complex kinematics including infall, rotation and outflow motions, and the interferometer data reveal these in greater detail. Interferometer data of N2H+ 1-0 suggest a very rapidly rotating flattened envelope between two young stellar objects, IRS1 and IRS2. Also, interferometer data of CO 2-1 resolve the outflow associated with L1251B seen in single-dish maps into a few narrow and compact components. Furthermore, the high resolution data support recent theoretical studies of molecular depletions and enhancements that accompany the formation of protostars within dense cores. Beyond L1251B, single-dish data are also presented of a dense core located 150" to the east that, in Paper I, was detected at 850 micron but has no associated point sources at near- and mid-infrared wavelengths. The relative brightness between molecules, which have different chemical timescales, suggests it is less chemically evolved than L1251B. This core may be a site for future star formation, however, since line profiles of HCO+, CS, and HCN show asymmetry with a stronger blue peak, which is interpreted as an infall signature.

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Evolution of the obliquities of the giant planets in encounters during migration

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Tsiganis et al. [Tsiganis, K., Gomes, R., Morbidelli, A., Levison, H.F., 2005. Nature 435, 459461] have proposed that the current orbital architecture of the outer Solar System could have been established if it was initially compact and Jupiter and Saturn crossed the 2:1 orbital resonance by divergent migration. The crossing led to close encounters among the giant planets, but the orbital eccentricities and inclinations were damped to their current values by interactions with planetesimals. Brunini [Brunini, A., 2006. Nature 440, 11631165] has presented widely publicized numerical results showing that the close encounters led to the current obliquities of the giant planets. We present a simple analytic argument which shows that the change in the spin direction of a planet relative to an inertial frame during an encounter between the planets is very small and that the change in the obliquity (which is measured from the orbit normal) is due to the change in the orbital inclination. Since the inclinations are damped by planetesimal interactions on timescales much shorter than the timescales on which the spins precess due to the torques from the Sun, especially for Uranus and Neptune, the obliquities should return to small values if they are small before the encounters. We have performed simulations using the symplectic integrator SyMBA, modified to include spin evolution due to the torques from the Sun and mutual planetary interactions. Our numerical results are consistent with the analytic argument for no significant remnant obliquities.

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Hubble and Spitzer Observations of an Edge-on Circumstellar Disk around a Brown Dwarf

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We present observations of a circumstellar disk that is inclined close to edge-on around a young brown dwarf in the Taurus star-forming region. Using data obtained with SpeX at the NASA Infrared Telescope Facility, we find that the slope of the 0.82.5 μm spectrum of the brown dwarf 2MASS J04381486+2611399 cannot be reproduced with a photosphere reddened by normal extinction. Instead, the slope is consistent with scattered light, indicating that circumstellar material is occulting the brown dwarf. By combining the SpeX data with mid-infrared photometry and spectroscopy from the Spitzer Space Telescope and previously published millimeter data from Scholz and coworkers, we construct the spectral energy distribution (SED) for 2MASS J04381486+2611399 and model it in terms of a young brown dwarf surrounded by an irradiated accretion disk. The presence of both silicate absorption at 10 μm and silicate emission at 11 μm constrains the inclination of the disk to be $\sim 70°$, i.e., $\sim 20°$ from edge-on. Additional evidence of the high inclination of this disk is provided by our detection of asymmetric bipolar extended emission surrounding 2MASS J04381486+2611399 in high-resolution optical images obtained with the Hubble Space Telescope. According to our modeling for the SED and images of this system, the disk contains a large inner hole that is indicative of a transition disk ($R_{in} \approx 58R_\star \approx 0.275$ AU) and is somewhat larger than expected from embryo ejection models (R_{out} = 2040 AU vs. Rout < 1020 AU).

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On the Distance to the Ophiuchus Star-Forming Region

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The Ophiuchus molecular cloud complex has produced in Lynds 1688 the richest known embedded cluster within ∼300 pc of the Sun. Unfortunately, distance estimates to the Oph complex vary by nearly ∼40% (∼120-165 pc). Here I calculate a new independent distance estimate of 135 ± 8 pc to this benchmark star-forming region based on Hipparcos trigonometric parallaxes to stars illuminating reflection nebulosity in close proximity to Lynds 1688. Combining this value with recent distance estimates from reddening studies suggests a consensus distance of 139 ± 6 pc (4% error), situating it within ∼11 pc of the centroid of the ∼5 Myr old Upper Sco OB subgroup of Sco OB2 (145 pc). The velocity vectors for Oph and Upper Sco are statistically indistinguishable within $\sim 1\,\mathrm{km\,s^{-1}}$ in each vector component. Both Oph and Upper Sco have negligible motion ($<1\,\mathrm{km\,s^{-1}}$) in the Galactic vertical direction with respect to the Local Standard of Rest, which is inconsistent with the young stellar groups having formed via the high velocity cloud impact scenario.

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An Improbable Solution to the Underluminosity of 2M1207B: A Hot Protoplanet Collision Afterglow

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We introduce an alternative hypothesis to explain the very low luminosity of the cool (L-type) companion to the $\sim$25 M_{Jup} $\sim$8 Myr-old brown dwarf 2M1207A. Recently, Mohanty et al. (2007) found that effective temperature estimates for 2M1207B (1600 ± 100 K) are grossly inconsistent with its lying on the same isochrone as the primary, being a factor of ∼10 underluminous at all bands between I (0.8 μm) and L' (3.6 μm). Mohanty et al. explain this discrepency by suggesting that 2M1207B is an 8 M_{Jup} object surrounded by an edge-on disk comprised of large dust grains producing 2.5^m of achromatic extinction. We offer an alternative explanation: the apparent flux reflects the actual source luminosity. Given the temperature, we infer a small radius (∼49,000 km), and for a range of plausible

densities, we estimate a mass $< M_{Jup}$. We suggest that 2M1207B is a hot protoplanet collision afterglow and show that the radiative timescale for such an object is $> \sim 1\%$ the age of the system. If our hypothesis is correct, the surface gravity of 2M1207B should be an order of magnitude lower than predicted by Mohanty et al. (2007).

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Planet dispersal in binary systems during transient multiple star phases

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Aims. If a significant fraction of binary star systems spent some time as inclined triple systems, either during their formation process or as the outcome of several close dynamical encounters in a crowded stellar environment, then the number of planets in binaries would be significantly lower than around single stars. The stellar chaotic phase preceding the instability of the triple system and the wide oscillations in eccentricity and inclination of the companion star due to the high mutual inclination between the companion and the singleton would quickly eject planets orbiting the binary in S-type orbits.

Methods. We perform numerical simulations of the dynamical evolution of hierarchical triple star systems with planets hosted around the primary star of the inner binary. Different values of mutual inclination, binary separation and singleton initial semimajor axis are explored in a statistical way.

Results. We find that a significant mutual inclination $i_{\rm m}$ between the singleton and the binary is a key factor for instability of the planetary system. When $i_{\rm m}$ is larger than $\sim 40^\circ$ the fraction of planets in the binary surviving the chaotic phase of the triple declines dramatically. The combination of eccentricity and inclination oscillations of the binary companion induced by the secular perturbations of the singleton and the sequence of close encounters preceding the ejection of one star fully destabilize a planetary system extending beyond 1 AU from the star. For $i_{\rm m}$ around 90° the percentage of surviving planets is lower than 20% for all binaries with a semimajor axis smaller than 200 AU.

Conclusions. The frequency of planets in binaries with low separation may be strongly reduced by the residence of the pair in the past in a temporary inclined hierarchical triple.

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SUBARU Near-Infrared Multi-Color Images of ClassII Young Stellar Object, RNO91

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We conducted sub-arcsecond near-infrared imaging observations of RNO91 with CIAO mounted on the SUBARU 8.2 m telescope. We present our JHK band data along with optical images, which when considered together reveal a complex circumstellar structure. We examined the colors of associated nebula and compared the geometry of the outflow/disk system suggested by our data with that already proposed on the basis of previous studies. Our K-band image shows bright circumstellar nebulosity detected within 2"(300AU) around the central source while it is less conspicuous at shorter wavelengths such as J and optical. P.A. and size of this red color nebulosity in our H-K color image agree with those of the previously detected polarization disk. These data agreement indicate that this bright

circumstellar nebulosity region which follows the reddening law might be attributed to a disk-like structure. At J and optical wavelengths, several blue knot-like structures are detected around and beyond the bright circumstellar nebulosity. We suggest that these knotty reflection nebulae may represent disintegrating fragments of an infalling envelope. The three-color composite image has an appearance of arc-shaped nebulosity extending to the north and to the east through the central source. On the other end of this arc-shaped structure, the nebula appears to become more extended (2.”3 long) to the southwest. We interpret these structures as roots of bipolar cavities opening to the northeast and southwest. The complex distribution of reflection nebulosity seen around RNO91 appears to confirm the interpretation of this source as an object dispersing its molecular envelope while transitioning from protostar to T Tauri star.

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The Effect of Binarity on Stellar Rotation: Beyond the Reach of Tides

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We present a comparison between the rotation period distributions of solar-type single stars and primary stars in close binaries (0.1 AU $\lesssim$ a $\lesssim$ 5 AU) in the young (∼150 Myr) open cluster M35 (NGC 2168). We find that the primary stars in the close binaries rotate faster than the single stars, on average. The differences in the means and medians between the period distributions are statistically significant at the 99.9% level or higher. The faster rotation among the primary stars in close binaries is not due to tidal synchronization as tidally evolved stars are excluded from the comparison. We discuss this result in the context of different early-evolution accretion processes and star-disk interactions for single stars and stars in close binaries.

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12 and 18 μm Images of Dust Surrounding HD 32297

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We present the first subarcsecond-resolution images at multiple mid-IR wavelengths of the thermally emitting dust around the A0 star HD 32297. Our observations with T-ReCS at Gemini South reveal a nearly edge-on resolved disk at both 11.7 and 18.3 μm that extends ∼150 AU in radius. The mid-IR is the third wavelength region in which this disk has been resolved, following coronagraphic observations by others of the source at optical and near-IR wavelengths. The global mid-IR colors and detailed consideration of the radial colortemperature distribution imply that the central part of the disk out to ∼80 AU is relatively deficient in dust.

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

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Context. Previous interferometric observations have demonstrated that, across a distance of a few 0.1 pc, the high-mass star forming region (SFR) G24.78+0.08 contains at least four distinct centers of massive star formation, possibly in different evolutionary stages.

Aims. This study aims to provide a detailed picture of the physical environment and the gas kinematics in a cluster of high-mass YSOs.

Methods. Using EVN (single epoch) and VLBA (four epochs) phase-referenced observations, we have derived the absolute positions and velocities for 6.7 GHz methanol and 22.2 GHz water masers, respectively. Using the BIMA and VLA interferometers, positions and line of sight velocities of 95 GHz and 44 GHz methanol masers, are also obtained. The derived interferometric and VLBI maser maps are compared with previous sub-arcsecond maps of the G24.78+0.08 region, observed in thermal continuum and molecular line tracers.

Results. In the hot molecular cores G24 A1 and G24 A2, 6.7 GHz methanol and 22.2 GHz water masers are emerging at similar positions and line of sight velocities, which suggests that in both cores a same YSO is responsible for the excitation of the two types of maser emission. At the center of the G24 A1 core, water masers distribute along an arc at the border of a hyper-compact HII region (of size ≈1000 AU) and expand away from the center of the HII region with high velocities (≈40 km s^{-1}). We think that such a fast expansion is driven by a strong stellar wind emitted by the star exciting the hyper-compact HII region. This outflowing motion might dominate the gas kinematics of G24 A1 also at larger (≈0.1 pc) scale, where a well defined velocity gradient in the CH_3CN line and 6.7 GHz masers is observed. Alternatively, water masers might mark the border of the dynamical interaction between the evolving star and harboring core, and the gas surrounding the hyper-compact HII region, not yet affected by the expansion of the ionized gas, might be still rotating and, perhaps, slightly contracting. In the G24 C core, water maser spots show very fast (100-200 km s^{-1}) and nearly parallel proper motions, which might indicate that the water maser emission is tracing a collimated jet.

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The RMS Survey: Mid-Infrared Observations of Candidate Massive YSOs in the Southern Hemisphere

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Context: The Red MSX Source (RMS) survey is an ongoing effort to return a large, well-selected sample of massive young stellar objects (MYSOs) within our Galaxy. 2000 candidates have been colour-selected from the Mid-course Space Experiment (MSX) point source catalogue (PSC). A series of ground-based follow-up observations are being undertaken in order to remove contaminant objects (ultra-compact HII (UCHII) regions, planetary nebulae (PN), evolved stars), and to begin characterising these MYSOs.

Aims: As a part of these follow-up observations, high resolution (∼1′′) mid-IR imaging aids the identification of contaminant objects which are resolved (UCHII regions, PN) as opposed to those which are unresolved (YSOs, evolved stars) as well as identifying YSOs near UCHII regions and other multiple sources.

Methods: We present 10.4μm imaging observations for 346 candidate MYSOs in the RMS survey in the Southern Hemisphere, primarily outside the region covered by the GLIMPSE Spitzer Legacy Survey. These were obtained using TIMMI2 on the ESO 3.6m telescope in La Silla, Chile. Our photometric accuracy is of order 0.05Jy, and our astrometric accuracy is 0.8′′, which is an improvement over the nominal 2′′ accuracy of the MSX PSC.

Results: Point sources are detected in 64% of our observations, which are expected to be either YSOs or evolved stars. 24% contain only sources of extended emission, which are likely to be either UCHII regions or, in a few cases, PN. This is confirmed by comparison with radio continuum observations. We find that, as expected for a dusty HII region, the

strength of 10.4μm and radio continuum emission is related. The remaining targets (12%) result in non-detections. While for 63% of our targets we detect only one mid-infrared source, 25% show multiple sources. In these cases, our observations will allow the apportioning of the flux from larger beam measurements between the different sources. Within these multiple source targets, we find some point sources on or near UCHII regions. Our improved astrometric information will allow more accurate targeting of spectroscopy, which will be used to identify unresolved sources in cases where it is not clear whether they are YSOs or evolved stars.

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Orbital solution and fundamental parameters of σ Scorpii

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The first orbital solution for the spectroscopic pair in the multiple star system σ Scorpii, determined from measurements with the Sydney University Stellar Interferometer, is presented. The primary component is of β Cephei variable type and has been one of the most intensively studied examples of its class. The orbital solution, when combined with radial velocity results found in the literature, yields a distance of 174^{+23}_{-18} pc, which is consistent with, but more accurate than the Hipparcos value. For the primary component we determine 18.4 ± 5.4 $M_\odot$, 4.12 ± 0.34 mag and 12.7 ± 1.8 $R_\odot$ for the mass, absolute visual magnitude and radius, respectively. A B1 dwarf spectral type and luminosity class for the secondary is proposed from the mass determination of 11.9 ± 3.1 $M_\odot$ and the estimated system age of 10 Myr.

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The Spitzer c2d Survey of Large, Nearby, Interstellar Clouds: VII. Ophiuchus Observed with MIPS

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We present maps of 14.4 sq deg of the Ophiuchus dark clouds observed by the Spitzer Space Telescope Multiband Imaging Photometer for Spitzer (MIPS). These high quality maps depict both numerous point sources as well as extended dust emission within the star-forming and non-star-forming portions of these clouds. Using PSF-fitting photometry, we detect 5779 sources at 24 um and 81 sources at 70 um at the 10 sigma level of significance. Three hundred twenty-three candidate young stellar objects (YSOs) were identified according to their positions on the MIPS/2MASS K versus K−[24] color-magnitude diagrams as compared to 24 um detections in the SWIRE extragalactic

survey. We find that more than half of the YSO candidates, and almost all the ones with protostellar Class I spectral energy distributions, are confined to the known cluster and aggregates.

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The Arecibo Methanol Maser Galactic Plane Survey - II: Statistical and Multi-wavelength Counterpart Analysis

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We present an analysis of the properties of the 6.7 GHz methanol maser sample detected in the Arecibo Methanol Maser Galactic Plane Survey. The distribution of the masers in the Galaxy, and statistics of their multi-wavelength counterparts is consistent with the hypothesis of 6.7 GHz maser emission being associated with massive young stellar objects. Using the detection statistics of our survey, we estimate the minimum number of methanol masers in the Galaxy to be 1275. The $l - v$ diagram of the sample shows the tangent point of the Carina-Sagittarius spiral arm to be around a Galactic longitude of 49.6 degrees, and suggests occurrence of massive star formation along the extension of the Crux-Scutum arm. A Gaussian component analysis of the maser spectra shows the mean line-width to be 0.38 km/s which is more than a factor of two larger than what has been reported in the literature. We also find no evidence that faint methanol masers have different properties than those of their bright counterparts.

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Do O-stars form in isolation?

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Around 4 per cent of O-stars are observed in apparent isolation, with no associated cluster, and no indication of having been ejected from a nearby cluster. We define an isolated O-star as a star >17.5 $M_\odot$ in a cluster with total mass <100 $M_\odot$ which contains no other massive (>10 $M_\odot$) stars. We show that the fraction of apparently isolated O-stars is reproduced when stars are sampled (randomly) from a standard initial mass function and a standard cluster mass function of the form $N(M) \propto M^{-2}$.

This result is difficult to reconcile with the idea that there is a fundamental relationship between the mass of a cluster and the mass of the most massive star in that cluster. We suggest that such a relationship is a typical result of star formation in clusters, and that 'isolated O-stars' are low-mass clusters in which massive stars have been able to form.

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The potential for Earth-mass planet formation around brown dwarfs

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Recent observations point to the presence of structured dust grains in the discs surrounding young brown dwarfs, thus implying that the first stages of planet formation take place also in the sub-stellar regime. Here, we investigate the potential for planet formation around brown dwarfs and very low mass stars according to the sequential core accretion model of planet formation. We find that, for a brown dwarfs mass $0.05M_\odot$, our models predict a maximum

planetary mass of $\sim 5M_\oplus$, orbiting with semi-major axis $\sim$ 1AU. However, we note that the predictions for the mass - semi-major axis distribution are strongly dependent upon the models chosen for the disc surface density profiles and the assumed distribution of disc masses. In particular, if brown dwarf disc masses are of the order of a few Jupiter masses, Earth-mass planets might be relatively frequent, while if typical disc masses are only a fraction of Jupiter mass, we predict that planet formation would be extremely rare in the sub-stellar regime. As the observational constraints on disc profiles, mass dependencies and their distributions are poor in the brown dwarf regime,we advise caution in validating theoretical models only on stars similar to the Sun and emphasise the need for observational data on planetary systems around a wide range of stellar masses. We also find that, unlike the situation around solar-like stars, Type-II migration is totally absent from the planet formation process around brown dwarfs, suggesting that any future observations of planets around brown dwarfs would provide a direct measure of the role of other types of migration.

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On the migration of protoplanets embedded in circumbinary disks

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Aims. We present the results of hydrodynamical simulations of low mass protoplanets embedded in circumbinary accretion disks. The aim is to examine the migration and long term orbital evolution of the protoplanets, in order to establish the stability properties of planets that form in circumbinary disks.

Methods. Simulations were performed using a grid-based hydrodynamics code. First we present a set of calculations that study how a binary interacts with a circumbinary disk. We evolve the system for $\sim 10^5$ binary orbits, which is the time needed for the system to reach a quasi-equilibrium state. From this time onward the apsidal lines of the disk and the binary are aligned, and the binary eccentricity remains essentially unchanged with a value of $e_\mathrm{b} \sim 0.08$. Once this stationary state is obtained, we embed a low mass protoplanet in the disk and let it evolve under the action of the binary and disk forces. We consider protoplanets with masses of $m_\mathrm{p} = 5$, 10 and 20 $M_\oplus$.

Results. In each case, we find that inward migration of the protoplanet is stopped at the edge of the tidally truncated cavity formed by the binary. This effect is due to positive corotation torques, which can counterbalance the net negative Lindblad torques in disk regions where the surface density profile has a sufficiently large positive gradient. Halting of migration occurs in a region of long-term stability, suggesting that low mass circumbinary planets may be common, and that gas giant circumbinary planets should be able to form in circumbinary disks.

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The nature of the dense core population in the Pipe Nebula: A survey of NH_3, CCS, and HC_5N molecular line emission

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Recent extinction studies of the Pipe Nebula (d=130 pc) reveal many cores spanning a range in mass from 0.2 to 20.4 $M_\odot$. These dense cores were identified via their high extinction and comprise a starless population in a very early stage of development. Here we present a survey of NH_3 (1,1), NH_3 (2,2), CCS (2_1–1_0), and HC_5N (9,8) emission toward 46 of these cores. An atlas of the 2MASS extinction maps is also presented. In total, we detect 63% of the cores in NH_3 (1,1), 22% in NH_3 (2,2), 28% in CCS, and 9% in HC_5N emission. We find the cores are associated with dense gas ($\sim 10^4\,\mathrm{cm}^{-3}$) with $9.5 \leq \mathrm{T_K} \leq 17$ K. Compared to $C^{18}O$, we find the NH_3 linewidths are systematically narrower, implying that the NH_3 is tracing the dense component of the gas and that these cores are relatively quiescent. We find

no correlation between core linewidth and size. The derived properties of the Pipe cores are similar to cores within other low-mass star-forming regions: the only differences are that the Pipe cores have weaker NH_3 emision and most show no current star formation as evidenced by the lack of embedded infrared sources. Such weak NH_3 emission could arise due to low column densities and abundances or reduced excitation due to relatively low core volume densities. Either alternative implies that the cores are relatively young. Thus, the Pipe cores represent an excellent sample of dense cores in which to study the initial conditions for star formation and the earliest stages of core formation and evolution.

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Visual Binaries in the Orion Nebula Cluster

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We have carried out a major survey for visual binaries towards the Orion Nebula Cluster, using images obtained with the Advanced Camera for Surveys on the Hubble Space Telescope through an Hα filter. Among 1051 stars more than $60''$ from θ^1 Ori C, we have selected 781 stars that fulfill criteria for membership in the Orion Nebula Cluster. Among these, we find 78 multiple systems (75 binaries and 3 triples), of which 55 are new discoveries, in the range from $0.1''$ to $1.5''$. We perform a statistical study of the 72 binaries and 3 triples that have separations in the limited range $0.15''$ to $1.5''$, within which we need no incompleteness correction. An analysis of the stellar density in our images suggests that of these binaries, 9 are line-of-sight associations. When corrected for this, we find a binary fraction of 8.8%$\pm$1.1% within the limited separation range from 67.5 to 675 AU (counting the 3 triples as 6 binaries). The field binary fraction in the same range from Duquennoy & Mayor (1991) is a factor 1.5 higher. Within the range 150 AU to 675 AU that overlaps with the study of binaries in T Tauri associations by Reipurth & Zinnecker (1993), we find that the associations have a factor 2.2 more binaries than the Orion Nebula Cluster, in approximate agreement with earlier results based on data from the inner Trapezium region with small-number statistics. The binary separation distribution function of the Orion Nebula Cluster shows unusual structure, with a sudden steep decrease in the number of binaries as the separation increases beyond $0.5''$, corresponding to 225 AU. We have measured the ratio of binaries wider than $0.5''$ to binaries closer than $0.5''$ as a function of distance from the Trapezium, and find that this ratio is significantly depressed in the inner region of the Orion Nebula Cluster. The deficit of binaries with larger separations in the central part of the cluster is likely due to dissolution or orbital change of the wider binaries during their passage through the potential well of the inner cluster region. All of our primaries appear to be T Tauri stars with the exception of one Herbig Ae/Be star, and there are indications that a substantial number of secondaries could be brown dwarfs.

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Evolution of protoplanetary discs driven by the MRI, self-gravity and hydrodynamical turbulence

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We study the viscous evolution of protoplanetary discs driven by the combined action of magnetohydrodynamic turbulence, resulting from the magneto-rotational instability (MRI), self-gravity torques, parametrized in terms of an effective viscosity and an additional viscous agent of unspecified origin. The distribution of torques driving the evolution of the disc is calculated by analysing where in the disc the MRI develops and, to incorporate the effect of self-gravity, calculating the Toomre parameter. We find that, generally, discs rapidly evolve towards a configuration where the intermediate regions, from a fraction of an au to a few au, are stable against the MRI due to their low-

ionization degree. As an additional source of viscosity is assumed to operate in those regions, subsequent evolution of the disc is eruptive. Brief episodes of high mass accretion ensue as the criterion for the development of the MRI is met in the low-ionization region. The radial distribution of mass and temperature in the disc differs considerably from disc models with constant parameter or layered accretion models, with potentially important consequences on the process of planet formation.

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Desorption From Interstellar Ices

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The desorption of molecular species from ice mantles back into the gas phase in molecular clouds results from a variety of very poorly understood processes. We have investigated three mechanisms; desorption resulting from H_2 formation on grains, direct cosmic ray heating and cosmic ray induced photodesorption. Whilst qualitative differences exist between these processes (essentially deriving from the assumptions concerning the species-selectivity of the desorption and the assumed threshold adsorption energies, E_t) all three processes are found to be potentially very significant in dark cloud conditions. It is therefore important that all three mechanisms should be considered in studies of molecular clouds in which freeze-out and desorption are believed to be important.

Employing a chemical model of a typical static molecular core and using likely estimates for the quantum yields of the three processes we find that desorption by H_2 formation probably dominates over the other two mechanisms. However, the physics of the desorption processes and the nature of the dust grains and ice mantles are very poorly constrained. We therefore conclude that the best approach is to set empirical constraints on the desorption, based on observed molecular depletions - rather than try to establish the desorption efficiencies from purely theoretical considerations. Applying this method to one such object (L1689B) yields upper limits to the desorption efficiencies that are consistent with our understanding of these mechanisms.

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A FLAMINGOS Deep Near Infrared Imaging Survey of the Rosette Complex I: Identification and Distribution of the Embedded Population

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We present the results of a deep near-infrared imaging survey of the Rosette Complex made with the Florida Multi-Object Imaging Spectrograph (FLAMINGOS) at the 2.1m telescope at Kitt Peak National Observatory. We studied the distribution of young embedded sources using a variation of the Nearest Neighbor Method applied to a carefully selected sample of near-infrared excess (NIRX) stars which trace the latest episode of star formation in the complex. Our analysis confirmed the existence of seven clusters previously detected in the molecular cloud, and identified four more clusters across the complex. We determined that 60% of the young stars in the complex and 86% of the stars within the molecular cloud are contained in clusters, implying that the majority of stars in the Rosette formed in embedded clusters. Also, half of the young embedded population is contained in four clusters that coincide with the central core of the cloud, where the main interaction between with the HII region is taking place. We compare the sizes, infrared excess fractions and average extinction towards individual clusters to investigate their early evolution and expansion. In particular, the size and degree of central condensation within the clusters appear to be related to the degree of infrared excess and mean extinction in a way that suggests that the clusters form as compact entities and then quickly expand after formation. We found that the average infrared excess fraction of clusters increases as a function of distance from NGC 2244, implying a temporal sequence of star formation across the complex. This sequence appears to be primordial, possibly resulting from the formation and evolution of the molecular cloud and not

from the interaction with the HII region. Instead, the main influence of the HII region could be to enhance or inhibit the underlying pattern of star formation in the cloud.

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Proper motions of radiative knots in simulations of stellar jets

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Aims. Elongated jets from young stellar objects typically present a nodular structure, formed by a chain of bright knots of enhanced emission with individual proper motions. Though it is generally accepted that internal shocks play an important role in the formation and dynamics of such structures, their precise origin and the mechanisms behind the observed proper motions is still a matter of debate. Our goal is to study numerically the origin, dynamics, and emission properties of such knots.

Methods. Axisymmetric simulations are performed with a shock-capturing code for gas dynamics, allowing for molecular, atomic, and ionized hydrogen in non-equilibrium concentrations subject to ionization/recombination processes. Radiative losses in [S II] lines are computed, and the resulting synthetic emission maps are compared with observations.

Results. We show that a pattern of regularly spaced internal oblique shocks, characterized by individual proper motions, is generated by the pressure gradient between the propagating jet and the time variable external cocoon. In the case of under-expanded, light jets the resulting emission knots are found to move downstream with the jet flow, with increasing velocity and decaying brightness toward the leading bow shock. This suggests that the basic properties of the knots observed in stellar jets can be reproduced even without invoking ad hoc pulsating conditions at the jet inlet, though an interplay between the two scenarios is certainly possible.

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Detection of C_6H^- toward the Low-Mass Protostar IRAS 04368+2557 in L1527

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We have detected the J = 76, 87, and 1514 lines of C_6H^- toward a low-mass star-forming region of L1527. We have also detected the J = 15/213/2 and 33/231/2 lines of the corresponding neutral species, C_6H, and the 81,871,7 line of C_6H_2 in L1527. This is the first detection of these three species in star-forming regions. The column density of C_6H^- is $(5.8 \pm 1.8) \times 10^{10}$ cm^{-2}, which is comparable to that in TMC-1, although the column density of C_6H in L1527 is about 1/5 of that in TMC-1. Hence, the $N(C_6H^-)/N(C_6H)$ ratio is 0.093 ± 0.029, which is higher than that in TMC-1 by a factor of 4. This high anion-to-neutral ratio is discussed in terms of a simplified chemical model.

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A multiwavelength study of Galactic HII region Sh2-294

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We present the observational results of Galactic HII region Sh2-294, using optical photometry, narrow-band imaging and radio continuum mapping at 1280 MHz, together with archival data from 2MASS, MSX and IRAS surveys. The stellar surface density profile based on 2MASS data indicates that the radius of the cluster associated with the Sh2-294 region is $\sim 2.3'$. We found an anomalous reddening law for the dust inside the cluster region and the ratio of total-to-selective extinction (R_V) is found to be 3.8 $\pm$ 0.1. We estimate the minimum reddening $E(B-V) = 1.35$ mag and distance of 4.8 $\pm$ 0.2 kpc to the region from optical color-color and color-magnitude diagrams. We identified the ionizing source of the HII region, and spectral type estimates based on different methods are consistent with a star of spectral type $\sim$ B0 V. The 2MASS JHK_s images reveal a partially embedded cluster associated with the ionizing source along with a small cluster towards the eastern border of Sh2-294. The ionization front seen along the direction of small cluster in radio continuum and Hα images, might be due to the interaction of ionizing sources with the nearby molecular cloud. We found an arc shaped diffuse molecular hydrogen emission at 2.12 μm and a half ring of MSX dust emission which surrounds the ionized gas in the direction of the ionization front. The $HIRES$ processed $IRAS$ maps show two clumpy structures of high optical depth (τ_{100}) and low color temperature ($T(60/100)$) at the eastern border of the nebula. Self consistent radiative transfer model of mid- to far-infrared continuum emission detected near small cluster is in good agreement with the observed spectral energy distribution of a B1.5 ZAMS star. The morphological correlation between the ionised and molecular gas, along with probable time scale involved between the ionising star, evolution of HII region and small cluster, indicates that the star-formation activity observed at the border is probably triggered by the expansion of HII region.

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The Nature of the Gould Belt from a Fractal Analysis of its Stellar Population

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The Gould Belt (GB) is a system of gas and young, bright stars distributed along a plane that is inclined with respect to the main plane of the Milky Way. Observational evidence suggests that the GB is our closest star formation complex, but its true nature and origin remain rather controversial. In this work we analyze the fractal structure of the stellar component of the GB. In order to do this, we tailor and apply an algorithm that estimates the fractal dimension in a precise and accurate way, avoiding both boundary and small data set problems. We find that early OB stars (of spectral types earlier than B4) in the GB have a fractal dimension very similar to that of the gas clouds in our Galaxy. On the contrary, stars in the GB of later spectral types show a larger fractal dimension, similar to that found for OB stars of both age groups in the local Galactic disk (LGD). This result seems to indicate that while the younger OB stars in the GB preserve the memory of the spatial structure of the cloud where they were born, older stars are distributed following a similar morphology as that found for the LGD stars. The possible causes for these differences are discussed.

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Coronal abundances of X-ray bright pre-main sequence stars in the Taurus molecular cloud

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Aims. We studied the thermal properties and chemical composition of the X-ray emitting plasma of a sample of bright members of the Taurus Molecular Cloud to investigate possible differences among classical and weak-lined T Tauri stars, and possible dependences of the abundances on the stellar activity level and/or on the presence of accretion/circumstellar material.

Methods. We used medium-resolution X-ray spectra obtained with the sensitive EPIC/PN camera in order to analyze the possible sample. The PN spectra of 20 bright ($L_X \sim 10^{30} - 10^{31}$ erg s^{-1}) Taurus members, with at least $\sim$ 4500 counts, were fitted using thermal models of optically thin plasma with two components and variable abundances of O, Ne, Mg, Si, S, Ar, Ca, and Fe. Extensive preliminary investigations were employed to study the performances of the PN detectors regarding abundance determinations, and finally to check the results of the fittings.

Results. We found that the observed X-ray emission of the studied stars can be attributed to coronal plasma having similar thermal properties and chemical composition both in the classical and in the weak-lined T Tauri stars. The results of the fittings did not reveal a correlation between the abundance patterns and activity or accretion/disk presence. The iron abundance of these active stars is significantly lower than the solar photospheric value ($\sim$ 0.2 solar). An indication of slightly different coronal properties in stars with different spectral type is found in this study. G-type and early K-type stars have, on average, slightly higher Fe abundances (Fe $\sim$ 0.24 solar) than stars with later spectral type (Fe $\sim$ 0.15 solar), confirming previous findings from high-resolution X-ray spectroscopy. Stars of the former group are also found to have, on average, hotter coronae.

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Relative velocities among accreting planetesimals in binary systems: the circumbinary case

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We numerically investigate the possibility of planetesimal accretion in circumbinary discs, under the coupled influence of both stars' secular perturbations and friction due to the gaseous component of the protoplanetary disc. We focus on one crucial parameter: the distribution of encounter velocities between planetesimals in the 0.5100 km size range. An extended range of binary systems with differing orbital parameters is explored. The resulting encounter velocities are compared to the threshold velocities below which the net outcome of a collision is accumulation into a larger body instead of mass erosion. For each binary configuration, we derive the critical radial distance from the binary barycentre beyond which planetesimal accretion is possible. This critical radial distance is smallest for equal-mass binaries on almost circular orbits. It shifts to larger values for increasing eccentricities and decreasing mass ratio. The importance of the planetesimals' orbital alignments of planetesimals due to gas drag effects is discussed.

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A multiwavelength study of the S106 region
III. The S106 molecular cloud as part of the Cygnus X cloud complex

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The distance to the well-known bipolar nebula S106 and its associated molecular cloud is highly uncertain. Values between 0.5 and 2 kpc are given in the literature, favoring a view of S106 as an isolated object at 600 pc distance as part of the 'Great Cygnus Rift'. However, there is evidence that S106 is physically associated with the Cygnus X complex at a distance of ∼1.7 kpc (Schneider et al. 2006). In this case, S106 is a more massive and more luminous star forming site as previously thought. We aim to understand the large-scale distribution of molecular gas in the S106 region, its possible association with other clouds in the Cygnus X south region, and the impact of UV radiation on the gas. This will constrain the distance to S106. We employ a part of an extended ^{13}CO and C^{18}O 1→0 survey, performed with the FCRAO, and data from the MSX and Spitzer satellites to study the spatial distribution and correlation of molecular cloud/PDR interfaces in Cygnus X south. The 2MASS survey is used to obtain a stellar density map of the region. We find evidence that several molecular clouds including S106 are directly shaped by the UV radiation from members of several Cygnus OB clusters, mainly NGC 6913, and are thus located at a distance of ∼1.7 kpc in the Cygnus X complex. The definition of OB associations in terms of spatial extent and stellar content in the Cygnus X south region is revised.

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The Detection and Characterization of Centimeter Radio Continuum Emission from the Low-Mass Protostar L1014-IRS

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Observations by the Cores to Disk Legacy Team with the Spitzer Space Telescope have identified a low-luminosity, mid-infrared source within the dense core, Lynds 1014, which was previously thought to harbor no internal source. Follow-up near-infrared and submillimeter interferometric observations have confirmed the protostellar nature of this source by detecting scattered light from an outflow cavity and a weak molecular outflow. In this paper, we report the detection of centimeter continuum emission with the VLA. The emission is characterized by a quiescent, unresolved 90 μJy 6 cm source within $0.2''$ of the Spitzer source. The spectral index of the quiescent component is $\alpha = 0.37 \pm 0.34$ between 6 and 3.6 cm. A factor of 2 increase in 6 cm emission was detected during one epoch and circular polarization was marginally detected at the 5 σ level with Stokes V/I = 48% ± 16%. We have searched for 22 GHz H_2O maser emission toward L1014-IRS, but no masers were detected during seven epochs of observations between 2004 June and 2006 December. L1014-IRS appears to be a low-mass, accreting protostar, which exhibits centimeter emission from a thermal jet or a wind, with a variable nonthermal emission component. The quiescent cm radio emission is noticeably above the correlation of 3.6 and 6 cm luminosity versus bolometric luminosity, indicating more radio emission than expected. In this paper, we characterize the centimeter continuum emission in terms of observations of other low-mass protostars, including updated correlations of centimeter continuum emission with bolometric luminosity and outflow force, and discuss the implications of recent larger distance estimates on the physical attributes of the protostar and dense molecular core.

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Brown dwarf formation by gravitational fragmentation of massive, extended protostellar discs

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We suggest that low-mass hydrogen-burning stars like the Sun should sometimes form with massive extended discs; and we show, by means of radiation hydrodynamic simulations, that the outer parts of such discs ($R \gtrsim 100\,\mathrm{AU}$) are likely

to fragment on a dynamical timescale (10^3 to 10^4 yr), forming low-mass companions: principally brown dwarfs (BDs), but also very low-mass hydrogen-burning stars and planetary-mass objects. A few of the BDs formed in this way remain attached to the primary star, orbiting at large radii. The majority are released into the field, by interactions amongst themselves; in so doing they acquire only a low velocity dispersion ($\lesssim 2\,\mathrm{km\,s^{-1}}$), and therefore they usually retain small discs, capable of registering an infrared excess and sustaining accretion. Some BDs form close BD/BD binaries, and these binaries can survive ejection into the field. This BD formation mechanism appears to avoid some of the problems associated with the 'embryo ejection' scenario, and to answer some of the questions not yet answered by the 'turbulent fragmentation' scenario.

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The Star Formation Law in a Multifractal ISM

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The surface density of the star formation rate in different galaxies, as well as in different parts of a single galaxy, scales nonlinearly with the surface density of the total gas. This observationally established relation is known as the Kennicutt-Schmidt star formation law. The slope of the star formation law has been shown to change with the density of the gas against which the star formation rate is plotted. This dependence implies a nonlinear scaling between the dense gas and the total gas surface densities within galaxies. Here, we explore a possible interpretation of this scaling as a property of the geometry of the interstellar medium (ISM), and we find that it arises naturally if the topology of the ISM is multifractal. Under the additional assumption that, at very high densities, the star formation timescale is roughly constant, the star formation law itself can also be recovered as a consequence of the multifractal geometry of the ISM. The slope of the scaling depends on the width of the global probability density function (PDF), and is between 1.5 and 1.6 for wide PDFs relevant to high-mass systems, while it is higher for narrower PDFs appropriate for lower-mass dwarf galaxies, in agreement with observations.

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A dense micro-cluster of Class 0 protostars in NGC 2264 D-MM1

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We present sensitive and high angular resolution ($\sim 1''$) 1.3 mm continuum observations of the dusty core D-MM1 in the Spokes cluster in NGC 2264 using the Submillimeter Array. A dense micro-cluster of seven Class 0 sources was detected in a $20'' \times 20''$ region with masses between 0.4 to $1.2\,M_\odot$ and deconvolved sizes of about 600 AU. We interpret the 1.3 mm emission as arising from the envelopes of the Class 0 protostellar sources. The mean separation of the 11 known sources (SMA Class 0 and previously known infrared sources) within D-MM1 is considerably smaller than the characteristic spacing between sources in the larger Spokes cluster and is consistent with hierarchical thermal fragmentation of the dense molecular gas in this region.

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Detection of Water Ice in Edge-on Protoplanetary Disks: HK Tauri B and HV Tauri C

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We report the first detection of 3 μm water ice absorption in a protoplanetary disk. Low-resolution spectroscopy with Subaru IRCS was carried out for two T Tauri stars with an edge-on disk, HK Tau B and HV Tau C. A 3 μm deep water ice absorption ($\tau \geq 1$) toward both objects was detected. Contribution by foreground cloud material to the ice absorption should be small, since $A_V \leq 3$ toward HK Tau A and HV Tau A, HV Tau B. Although HV Tau C is reported to have a small amount of envelope material, its mass is insufficient to produce the large optical depth of the detected water ice. In addition, HK Tau B does not have any significant envelope mass. Therefore, the water ice exists inside the disks of these objects. The optical depth profile of the water ice absorption in the protoplanetary disks does not show any significant difference from those of protostellar sources. The water ice optical depth for HV Tau C showed a large variation ($\Delta\tau = 0.59$) in two observing epochs separated by 2.32 yr. Assuming the ice absorption comes from a spherical cloud at 100 AU and Keplerian rotation, it suggests that a Pluto mass gas and dust cloud with a size of 1.4 AU may have passed by the line of sight. The lack of variability of the continuum level of HV Tau C at the two epochs implies that the dust grains with an icy mantle are segregated from the grains without an icy mantle.

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VLBA determination of the distance to nearby star-forming regions II. Hubble 4 and HDE 283572 in Taurus

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The non-thermal 3.6 cm radio continuum emission from the naked T Tauri stars Hubble 4 and HDE 283572 in Taurus has been observed with the Very Long Baseline Array (VLBA) at 6 epochs between September 2004 and December 2005 with a typical separation between successive observations of 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 uniform proper motion. The best fits yield distances to Hubble 4 and HDE 283572 of 132.8 $\pm$ 0.5 and 128.5 $\pm$ 0.6 pc, respectively. Combining these results with the other two existing VLBI distance determinations in Taurus, we estimate the mean distance to the Taurus association to be 137 pc with a dispersion (most probably reflecting the depth of the complex) of about 20 pc.

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The RMS Survey: ^{13}CO observations of candidate massive YSOs in the southern Galactic plane

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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 MYSOs candidates located within our Galaxy by comparing the colours of MSX and 2MASS point sources to those of known MYSOs. The aim of our follow-up observations is to identify other contaminating objects such as ultra compact (UC) HII regions, evolved stars and planetary nebulae (PNe) and distinguish between genuine MYSOs and nearby low-mass YSOs.
Aim: A critical part of our follow-up programme is to conduct ^{13}CO molecular line observations in order to determine kinematic distances to all of our MYSO candidates. These distances will be used in combination with far-IR and (sub)millimetre fluxes to determine bolometric luminosities which will allow us to identify and remove nearby low-mass YSOs. In addition these molecular line observations will help in identifying evolved stars which are weak CO emitters.
Method: We have used the 22 m Mopra telescope, the 15 m JCMT and the 20 m Onsala telescope to conduct molecular line observations towards 854 MYSOs candidates located in the 3rd and 4th quadrants. These observations have been made at the J=1–0 (Mopra and Onsala) and J=2–1 (JCMT) rotational transition frequency of ^{13}CO molecules and have a spatial resolution of $\sim 20''$–$40''$, a sensitivity of $T_A^* \simeq 0.1$ K and a velocity resolution of ~ 0.2 km s^{-1}.
Results: We detect ^{13}CO emission towards a total of 752 of the 854 RMS sources observed (∼ 88%). In total 2132 emission components are detected above 3σ level (typically $T_A^* \geq 0.3$ K). Multiple emission profiles are observed towards the majority of these sources – 461 sources (∼60%) – with an average of ∼4 molecular clouds detected along the line of sight. These multiple emission features make it difficult to assign a kinematic velocity to many of our sample. We have used archival CS (J=2–1) and maser velocities to resolve the component multiplicity towards 82 sources and have derived a criterion which is used to identify the most likely component for a further 218 multiple component sources. Combined with the single component detections we have obtained unambiguous kinematic velocities towards 591 sources (∼80% of the detections). The 161 sources for which we have not been able to determine the kinematic velocity will require additional line data. Using the rotation curve of Brand and Blitz (1993) and their radial velocities we calculate kinematic distances for all components detected.

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Chemistry in Protoplanetary Disks: A Sensitivity Analysis

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We study how uncertainties in the rate coefficients of chemical reactions in the RATE 06 database affect abundances and column densities of key molecules in protoplanetary disks. We randomly varied the gas-phase reaction rates within their uncertainty limits and calculated the time-dependent abundances and column densities using a gas-grain chemical model and a flaring steady-state disk model. We find that key species can be separated into two distinct groups according to the sensitivity of their column densities to the rate uncertainties. The first group includes CO, C^+, H_3^+, H_2O, NH_3, N_2H^+, and $HCNH^+$. For these species, the column densities are not very sensitive to the rate uncertainties but the abundances in specific regions are. The second group includes CS, CO_2, HCO^+, H_2CO, C_2H, CN, HCN, HNC and other, more complex species, for which high abundances and abundance uncertainties co-exist in the same disk region, leading to larger scatters in the column densities. However, even for complex and heavy molecules, the dispersion in their column densities is not more than a factor of ∼ 4. We perform a sensitivity analysis of the computed abundances to rate uncertainties and identify those reactions with the most problematic rate coefficients. We conclude that the rate coefficients of about a hundred of chemical reactions need to be determined more accurately in order to greatly improve the reliability of modern astrochemical models. This improvement should be an ultimate

goal for future laboratory studies and theoretical investigations.

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Spatial simulations of the Kelvin-Helmholtz instability in astrophysical jets: A partial stabilization mechanism for weakly magnetized transonic flows

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Aims. The long term magnetohydrodynamic stability of magnetized transonic/supersonic jets is numerically investigated using a spatial approach. We focus on two-dimensional linearly-unstable slab configurations where the jet is embedded in a flow-aligned uniform magnetic field of weak amplitude. We compare our results with previous studies using a temporal approach where longitudinally periodic domains were adopted.

Methods. The finite-volume based versatile advection code is used to solve the full set of ideal compressible MHD equations. We follow the development of Kelvin-Helmholtz modes that are driven by a white noise perturbation continuously introduced at the jet inlet.

Results. No noticeable difference is observed in spatial simulations versus analogous temporal ones during the linear and early non-linear evolution of the configuration. However, in the case of transonic flows, a different long-term scenario occurs in our spatial runs. Indeed, after the large-scale disruption of the flow, a sheath region of enhanced magnetic field encompassing the jet core forms along the whole flow. This provides a partial stabilization mechanism leading to enhanced stability for later times, which is almost independent of the initial magnitude of the magnetic field. The implication of this mechanism for the stability of astrophysical jets is discussed.

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The evolution of interstellar clouds in a streaming hot plasma including heat conduction

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Context. The interstellar medium contains warm clouds that are embedded in a hot dilute gas produced by supernovae. Because both gas phases are in contact, an interface forms where mass and energy are exchanged. Whether heat conduction leads to evaporation of these clouds or whether condensation dominates has been analytically derived. Both phases behave differently dynamically so that their relative motion has to be taken into account.

Aims. Real clouds in static conditions that experience saturated heat conduction are stabilized against evaporation if self-gravity and cooling play a role. Here, we investigte to what extent heat conduction can hamper the dynamical disruption of clouds embedded in a streaming hot plasma.

Methods. To examine the evolution of giant molecular clouds in the stream of a hot plasma we performed two-dimensional hydrodynamical simulations that take full account of self-gravity, heating and cooling effects and heat conduction by electrons. We use the thermal conductivity of a fully ionized hydrogen plasma proposed by Spitzer and a saturated heat flux according to Cowie & McKee in regions where the mean free path of the electrons is large compared to the temperature scaleheight.

Results. Significant structural and evolutionary differences occur between simulations with and without heat conduction. Dense clouds in pure dynamical models experience dynamical destruction by Kelvin-Helmholtz (KH) instability. In static models heat conduction leads to evaporation of such clouds. Heat conduction acting on clouds in a gas stream smooths out steep temperature and density gradients at the edge of the cloud because the conduction timescale is shorter than the cooling timescale. This diminishes the velocity gradient between the streaming plasma and the cloud, so that the timescale for the onset of KH instabilities increases, and the surface of the cloud becomes less susceptible

to KH instabilities. The stabilisation effect of heat conduction against KH instability is more pronounced for smaller and less massive clouds. As in the static case more realistic cloud conditions allow heat conduction to transfer hot material onto the cloud's surface and to mix the accreted gas deeper into the cloud.

Conclusions. In contrast to pure dynamical models of clouds in a plasma and to analytical considerations of heat conduction that can evaporate such clouds embedded in a hot plasma, our realistic numerical simulations demonstrate that this destructive effect of KH instability is significantly slowed by heat conduction so that clouds can survive their passage through hot gas.

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Self-regulated gravitational accretion in protostellar discs

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We present a numerical model for the evolution of a protostellar disc that has formed self-consistently from the collapse of a molecular cloud core. The global evolution of the disc is followed for several million years after its formation. The capture of a wide range of spatial and temporal scales is made possible by use of the thin-disc approximation. We focus on the role of gravitational torques in transporting mass inward and angular momentum outward during different evolutionary phases of a protostellar disc with disc-to-star mass ratio of order 0.1. In the early phase, when the infall of matter from the surrounding envelope is substantial, mass is transported inward by the gravitational torques from spiral arms that are a manifestation of the envelope-induced gravitational instability in the disc. In the late phase, when the gas reservoir of the envelope is depleted, the distinct spiral structure is replaced by ongoing irregular nonaxisymmetric density perturbations. The amplitude of these density perturbations decreases with time, though this process is moderated by swing amplification aided by the existence of the disc's sharp outer edge. Our global modelling of the protostellar disc reveals that there is typically a residual nonzero gravitational torque from these density perturbations, i.e. their effects do not exactly cancel out in each region. In particular, the net gravitational torque in the inner disc tends to be negative during first several million years of the evolution, while the outer disc has a net positive gravitational torque. Our global model of a self-consistently formed disc shows that it is also self-regulated in the late phase, so that it is near the Toomre stability limit, with a near-uniform Toomre parameter $Q \approx 1.5 - 2.0$. Since the disc also has near-Keplerian rotation, and comparatively weak temperature variation, it maintains a near-power-law surface density profile proportional to $r^{-3/2}$.

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New ammonia masers towards NGC6334I

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We report the detection of new ammonia masers in the non-metastable (8,6) and (11,9) transitions towards the massive star forming region NGC 6334I. Observations were made with the ATCA interferometer and the emitting region appears unresolved in the 2.7" $\times$ 0.8" beam, with deconvolved sizes less than an arcsecond. We estimate peak brightness temperatures of 7.8×10^5 and 1.2×10^5 K for the (8,6) and (11,9) transitions, respectively. The masers appear coincident both spatially and in velocity with a previously detected ammonia (6,6) maser. We also suggest that emission in the (10,9), (9,9) and (7,6) transitions may also be masers, based on their narrow line widths and overlapping velocity ranges with the above masers, as observed with the single-dish Mopra radiotelescope.

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The James Clerk Maxwell Telescope Legacy Survey of Nearby Star-forming Regions in the Gould Belt

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This paper describes a James Clerk Maxwell Telescope (JCMT) legacy survey that has been awarded roughly 500 hr of observing time to be carried out from 2007 to 2009. In this survey, we will map with SCUBA-2 (Submillimetre Common-User Bolometer Array 2) almost all of the well-known low-mass and intermediate-mass star-forming regions within 0.5 kpc that are accessible from the JCMT. Most of these locations are associated with the Gould Belt. From these observations, we will produce a flux-limited snapshot of star formation near the Sun, providing a legacy of images, as well as point-source and extended-source catalogs, over almost 700 deg^2 of sky. The resulting images will yield the first catalog of prestellar and protostellar sources selected by submillimeter continuum emission, and should increase the number of known sources by more than an order of magnitude. We will also obtain with the array receiver HARP (Heterodyne Array Receiver Program) CO maps, in three CO isotopologues, of a large typical sample of prestellar and protostellar sources. We will then map the brightest hundred sources with the SCUBA-2 polarimeter (POL-2), producing the first statistically significant set of polarization maps in the submillimeter. The images and source catalogs will be a powerful reference set for astronomers, providing a detailed legacy archive for future telescopes, including ALMA, Herschel, and JWST

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The development of a protoplanetary disk from its natal envelope

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Class 0 protostars, the youngest type of young stellar objects, show many signs of rapid development from their initial, spheroidal configurations, and therefore are studied intensively for details of the formation of protoplanetary disks within protostellar envelopes. At millimetre wavelengths, kinematic signatures of collapse have been observed in several such protostars, through observations of molecular lines that probe their outer envelopes. It has been suggested that one or more components of the proto-multiple system NGC 1333IRAS 4 may display signs of an embedded region that is warmer and denser than the bulk of the envelope. Here we report observations that reveal details of the core on Solar System dimensions. We detect in NGC 1333IRAS 4B a rich emission spectrum of H_2O, at wavelengths 2037 μm, which indicates an origin in extremely dense, warm gas. We can model the emission as infall from a protostellar envelope onto the surface of a deeply embedded, dense disk, and therefore see the development of a protoplanetary disk. This is the only example of mid-infrared water emission from a sample of 30 class 0 objects, perhaps arising from a favourable orientation; alternatively, this may be an early and short-lived stage in the evolution of a protoplanetary disk.

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Signatures of inflow motion in cores of massive star formation: Potential collapse candidates

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Using the IRAM 30 m telescope, a mapping survey in optically thick and thin lines was performed towards 46 high mass star-forming regions. The sample includes UC HII precursors and UC HII regions. Seventeen sources are found to show "blue profiles", the expected signature of collapsing cores. The excess of sources with blue over red profiles ($[N_{\rm blue} - N_{\rm red}]/N_{\rm total}$) is 29% in the HCO^+ J=1–0 line, with a probability of 0.6% that this is caused by random fluctuations. UC HII regions show a higher excess (58%) than UC HII precursors (17%), indicating that material is still accreted after the onset of the UC HII phase. Similar differences in the excess of blue profiles as a function of evolutionary state are not observed in low mass star-forming regions. Thus, if confirmed for high mass star-forming sites, this would point at a fundamental difference between low- and high-mass star formation. Possible explanations are inadequate thermalization, stronger influence of outflows in massive early cores, larger gas reserves around massive stellar objects or different trigger mechanisms between low- and high- mass star formation.

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Light-induced disassembly of dusty bodies in inner protoplanetary discs: implications for the formation of planets

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Laboratory experiments show that a solid-state greenhouse effect in combination with thermophoresis can efficiently erode a dust bed in a low-pressure gaseous environment. The surface of an illuminated, light absorbing dusty body is cooler than the dust below the surface (solid-state greenhouse effect). This temperature gradient leads to a directed momentum transfer between gas and dust particles and the dust particles are subject to a force towards the surface (thermophoresis). If the thermophoretic force is stronger than gravity and cohesion, dust particles are ejected. Applied to protoplanetary discs, dusty bodies smaller than several kilometres in size which are closer to a star than ~ 0.4 au are subject to a rapid and complete disassembly to submillimetre size dust aggregates by this process. While an inward-drifting dusty body is destroyed, the generated dust is not lost for the disc by sublimation or subsequent accretion on to the star but can be reprocessed by photophoresis or radiation pressure. Planetesimals cannot originate through aggregation of dust inside the erosion zone. If objects larger than several kilometres already exist, they prevail and further grow by collecting dust from disassembled smaller bodies. The pile-up of solids in a confined inner region of the disc, in general, boosts the formation of planets. Erosion is possible in even strongly gas-depleted inner regions as observed for TW Hya. Reprocessing of dust through light-induced erosion offers one possible explanation for growth of large cores of gas-poor giant planets in a gas-starved region as recently found around HD 149026b.

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Large-Scale Gravitational Instability and Star Formation in the Large Magellanic Cloud

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Large-scale star formation in disk galaxies is hypothesized to be driven by global gravitational instability. The observed gas surface density is commonly used to compute the strength of gravitational instability, but according to this criterion star formation often appears to occur in gravitationally stable regions. One possible reason is that the stellar contribution to the instability has been neglected. We have examined the gravitational instability of the Large Magellanic Cloud (LMC) considering the gas alone, and considering the combination of collisional gas and collisionless stars. We compare the gravitationally unstable regions with the on-going star formation revealed by *Spitzer* observations of young stellar objects. Although only 62% of the massive young stellar object candidates are in regions where the gas alone is unstable, some 85% lie in regions unstable due to the combination of gas and stars. The combined stability analysis better describes where star formation occurs. In agreement with other observations and numerical models, a small fraction of the star formation occurs in regions with gravitational stability parameter $Q > 1$. We further measure the dependence of the star formation timescale on the strength of gravitational instability, and quantitatively compare it to the exponential dependence expected from numerical simulations.

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Detection of Warm Molecular Hydrogen in the Circumstellar Disk around the Herbig Ae Star HD 97048

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We present high-resolution spectroscopic mid-infrared observations of the circumstellar disk around the Herbig Ae star HD 97048 with the VLT Imager and Spectrometer for the mid-InfraRed (VISIR). We detect the S(1) pure rotational

line of molecular hydrogen (H_2) at 17.035 μm arising from the disk around the star. This detection reinforces the claim that HD 97048 is a young object surrounded by a flared disk at an early stage of evolution. The emitting warm gas is located within the inner 35 AU of the disk. The line-to-continuum flux ratio is much higher than expected from models of disks at local thermodynamic equilibrium. We investigate the possible physical conditions, such as a gas-to-dust mass ratio higher than 100 and different excitation mechanisms of molecular hydrogen (e.g., X-ray heating, shocks), that would explain the detection. We tentatively estimate the mass of warm gas to be in the range from 10^{-2} to nearly 1 M_{Jup}. Further observations are needed to better constrain the excitation mechanisms as well as the mass of gas.

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Discs of planetary-mass objects in σ Orionis

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Aims. We searched for infrared flux excesses of planetary-mass candidates in the σ Orionis cluster ($\sim$ 3 Myr, $\sim$ 350 pc).

Methods. Using $IJHK_s$ data from the literature and the [3.6], [4.5], [5.8], and [8.0] IRAC images of the σ Orionis cluster from the Spitzer Space Telescope public archives, we constructed colour-colour diagrams and spectral energy distributions from 0.8 to 8.0 μm of cluster candidates fainter than J = 18.0 mag, i.e. the planetary-mass borderline for σ Orionis.

Results. Infrared flux excesses are detected longward of 5 μm in seven objects (S Ori 54, 55, 56, 58, 60, S Ori J053956.8-025315 and S Ori J053858.6-025228) with masses estimated in the range 7-14 $M_{\rm Jup}$. Emission at shorter wavelengths (4.5 μm) in excess of the photosphere is probably observed in S Ori 56 and S Ori J053858.6-025228. The faintest and least massive object, S Ori 60, exhibits flux excess only at 8 μm. We ascribe these infrared excesses to the presence of circumsubstellar warm discs, providing additional confirmation for the objects' membership of σ Orionis. The observed incidence of inner discs around planetary-mass objects is $\geq$50%, which is consistent with the measured inner disc frequency among cluster brown dwarfs and low-mass stars, suggesting that these objects share a common origin. However, there is a trend for the inner disc rate to increase with decreasing mass (from 10 $M_\odot$ through the substellar domain), which may be due to a mass-dependent timescale for the dissipation of the interior discs.

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Triggered star formation on the borders of the Galactic H II region RCW 120

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Context. To investigate the process of star formation triggered by the expansion of an H II region, we present a multi-wavelength analysis of the Galactic H II region RCW 120 and its surroundings. The collect and collapse model

predicts that the layer of gas and dust accumulated between the ionization and shock fronts during the expansion of the H II region collapses and forms dense fragments, giving rise to potential sites of massive-star formation.

Aims. The aim of our study is to look for such massive fragments and massive young stars on the borders of RCW 120. Methods.We mapped the RCW 120 region in the cold dust continuum emission at 1.2 mm to search for these fragments. We supplemented this study with the available near- (2MASS) and mid-IR (GLIMPSE) data to locate the IR sources observed towards this region and to analyse their properties. We then compared the observational results with the predictions of Hosokawa & Inutsuka's model (2005, ApJ, 623, 917; 2006, ApJ, 646, 240).

Results. At 1.2 mm we detected eight fragments towards this region, five located on its borders. The largest fragment has a mass of about 370 $M_{\odot}$. Class I and Class II young stellar objects are detected all over the region, with some observed far from the ionization front. This result emphasises the possible importance of distant interactions between the radiation, escaping from the ionized region, and the surrounding medium.

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Post-oligarchic Evolution of Protoplanetary Embryos and the Stability of Planetary Systems

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In the sequential accretion model, planets form through the sedimentation of dust, cohesive collisions of planetesimals, and coagulation of protoplanetary embryos prior to the onset of efficient gas accretion. As progenitors of terrestrial planets and the cores of gas giant planets, embryos have comparable masses and are separated by the full width of their feeding zones after the oligarchic growth. Within this context, we investigate the orbit-crossing time (T_c) of protoplanetary systems with equal planetary masses and initial separation k_0 scaled by their mutual Hill radii ("EMS systems"). In a gas-free environment, log $[T_c/(1\ \mathrm{yr})] \simeq$ A + B log $(k_0/2.3)$, where A and B are functions of the planetary masses and initial eccentricities. This power law is caused by a random-walk diffusion of velocity dispersion σ(t) in the EMS systems. The diffusion also leads to (1) a Rayleigh distribution of eccentricities with probability $P(t) = (e/\sigma^2) \exp[-e^2/(2\sigma^2)]$ at time t and (2) an evolution of average eccentricity $\propto t^{1/2}$. As evidence of this chaotic diffusion, the observed eccentricities of known extrasolar planets obey a Rayleigh distribution. In a gaseous environment, as embryos become well separated (with $k_0 \simeq$ 6-12), their orbit-crossing tendency is suppressed by tidal drag, and their growth is stalled as their orbits are circularized. We evaluate the isolation masses of the embryos, which determine the probability of gas giant formation, as a function of the dust and gas surface densities.

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Planetesimal Accretion onto Growing ProtoGas Giant Planets

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The solar and extrasolar gas giants appear to have diverse internal structure and metallicities. We examine a potential cause for these dispersions in the context of the conventional sequential accretion formation scenario. In principle, gas accretion onto cores with masses below several times that of the Earth is suppressed by the energy released from the bombardment of residual planetesimals. Due to their aerodynamical and tidal interaction with the nascent gas disk, planetesimals on eccentric orbits undergo slow orbital decay. We show that these planetesimals generally cannot pass through the mean motion resonances of the cores, and the suppression of planetesimal bombardment rate enables the cores to accrete gas with little interruption, thus shortening the timescale of gas giant formation. During growth from the cores to protoplanets, resonances overlap with each other, which strongly enhances the eccentricity excitation

of the trapped planetesimals. Subsequent gas drag induces the planetesimals to migrate to the proximity of the protoplanets and collide with them. This process leads to the resumption and a surge of planetesimal bombardment during the advanced stage of the protoplanet growth. Intruder planetesimals with different masses can either be resolved in the envelope or reach the core of the protoplanets. This mechanism may account for the diversity of the core-envelope structure between Jupiter, Saturn, and the metallicity dispersion inferred from the transiting extrasolar planets. During the final formation stage of the protogas giants, gap opening in gas disk leads to the accumulation of planetesimals outside the feeding zone of the protoplanets. The surface density enhancement promotes the subsequent buildup of cores for secondary gas giant planets outside the orbit of the first-born protoplanets and the formation of eccentric multiple planet systems.

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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 studies of gas in protoplanetary disks

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Ph.D degree awarded: July 2007

The gas dominates the mass and dynamics of protoplanetary disks. However, very few observational constraints exist about the physical properties of the gas in the planet forming region of the disks. This thesis presents an ensemble of new observational projects aimed at studying the gas in the disks of selected nearby Herbig Ae/Be stars (HAEBES) and classical T Tauri stars (CTTS). In the first chapter we present a search for CO 4.7 μm ro-vibrational emission from HAEBES using ISAAC, ESO's first generation VLT near-infrared spectrograph. In the second chapter, we describe a project in which we intended to probe the outer cold gas of protoplanetary disks, by measuring gas absorption features of the disk superimposed on the optical spectra of close (<1.5") visual companions of nearby HAEBES utilizing FORS2, ESO's VLT optical spectrograph. In the third chapter, we present a large observational effort to detect H_2 fundamental rotational emission at 12.278 and 17.035 μm from HAEBES employing VISIR, ESO's new high-resolution mid-infrared spectrograph. In the fourth chapter, we describe the first results of a sensitive search for near-infrared H_2 ro-vibrational emission at 2.1218, 2.2233 and 2.2477 μm in the CTTS LkHα 264 and the debris disk 49 Cet using CRIRES, ESO's new VLT near-infrared high-resolution spectrograph. From our observations (detections and non-detections), we derive important constraints on the physical properties of the studied disks (e.g. mass, column density, temperature, age, excitation mechanism, inclination). We show that high-resolution infrared spectroscopy is a crucial tool for future studies of the structure of protoplanetary disks.

1-10 Myr-old Low Mass Stars and Brown Dwarfs in Nearby Star Forming Regions

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Ph.D dissertation directed by: Lynne Hillenbrand

Ph.D degree awarded: July 2007

My thesis research has focused primarily on identifying and characterizing pre-main sequence stars in nearby star-forming regions. To this end, I carried out wide-field (∼150–250 deg^2) optical photometric and spectroscopic surveys in and near the star forming regions of Taurus and Upper Scorpius.

In Taurus, the aim of my optical photometric/spectroscopic survey was specifically to probe for a population of intermediate-age pre-main sequence stars outside of the young subclusters that are known to contain most of the young Taurus population. From this work, I found tens of young (∼1–3 Myr) and intermediate-age (∼5–10 Myr) stars both near the known Taurus population and to the east, but relatively few pre-main sequence stars of any age to the west. I argued that the new pre-main sequence stars identified far from Taurus can not have originated from the vicinity of the 1-2 Myr-old subclusters, and I proposed instead that they comprise a new, previously undiscovered region of recent star formation.

In USco, the aim of my optical photometric/spectroscopic survey was to probe beyond previously explored regions to identify large numbers of 5 Myr-old low mass stars. From the spectroscopic data, I have discovered 145 low mass members of USco. Using Monte Carlo simulations I showed that, taking into account known observational errors, the observed age dispersion for the low mass population in USco is consistent with all stars forming in a single burst ∼5 Myr ago. I also derived the first spectroscopic mass function for USco that extends into the substellar regime, and compared results to similar mass functions derived for stars in four other young clusters and associations.

Star Formation Postdoctoral Fellowship, University of Florida

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URL1: http://www.astro.ufl.edu/starformation.html
URL2: http://www.astro.ufl.edu/theory

The Department of Astronomy at the University of Florida (UF) invites applications for a Star Formation Postdoctoral Fellowship. The successful applicant will submit a research proposal to work in one or more of the following areas: local Galactic star and star cluster formation, global star formation activity of disk galaxies, star formation near AGN and the Galactic Center, and star formation in the early universe. Both observational and theoretical applications will be considered. Research proposals with potential for collaborations with the UF star formation and/or theory groups are encouraged.

UF faculty involved in star formation research include Steve Eikenberry, Elizabeth Lada, Jonathan Tan, and Charlie Telesco. Theoretical work includes analytic and numerical calculations of the formation of massive star formation, giant molecular cloud formation, and galactic scale star formation (Tan). Observational programs involve a wide range of star formation topics and facilities, including GEMINI-FLAMINGOS-2 surveys of embedded star clusters (Lada) and the Galactic Center (Eikenberry), and a variety of Gran-Telescopio Canarias (10m optical/IR) projects.

The position is an annual appointment, renewable for up to three years based on satisfactory performance, starting in or around Aug. 2008, with a salary of $45,000. Applicants should have a recent PhD., preferably in a star formation related field. Further information is available from Jonathan Tan (jt *at* astro.ufl.edu).

Application materials (CV, bibliography, statement of research interests and plans [no more than 3 pages plus 2 pages for figures], and three letters of reference [candidates are responsible for having their reference letters sent to UF]) should be mailed to the above address or emailed to Jonathan Tan (jt *at* astro.ufl.edu) by 15th December 2007.

The University of Florida is an Equal Opportunity Institution.

Postdoctoral Fellowship on Young Stellar Objects, their Surroundings and Jets

Expires: October 30, 2007

INAF - Osservatorio Astronomico di Palermo (Italy) will appoint one fellow in the area of ”Young Stellar Objects, their Surroundings and Jets”, under a Marie Curie Transfer of Knowledge grant. The fellowship is expected to start before the end of 2007 (negotiable) and to last 24 months. **The successful candidate is expected to have experience on data analysis and emission processes in the radio and/or infrared and/or optical and/or X-ray bands.**

Candidates should have a PhD or at least four years of full-time research experience at postgraduate level in a relevant field. In either case the candidate cannot have more than ten years of research experience.

Gross salary is fixed at 3889.25 Euro per month, for the duration of the contract, plus a mobility allowance.

Female candidates are explicitly encouraged to apply.

For eligibility and application details please check the PHOENIX website
http://www.astropa.unipa.it/~orlando/PHOENIX/POSITION/

All documents should arrive by October 30, 2007 at:

INAF - Osservatorio Astronomico di Palermo
Marie Curie Fellowship Selection (PHOENIX)
Piazza del Parlamento 1
I-90134 Palermo,
ITALY

For further information contact:
Salvatore Orlando - orlando *at* astropa.inaf.it
or visit
http://www.astropa.unipa.it/~orlando/PHOENIX

Meetings

Astrobiology Science Conference 2008 Topical Session: Chemical Constraints on the Formation and Evolution of Habitable Worlds

This session will focus on understanding the origin and evolution of organic molecules and other volatiles in planet-forming disks, and the processes that lead to the formation of a habitable planetary system including topics such as: a) constraining the major element composition and the origin of volatiles in terrestrial planets; b) the evolution of organic compounds in primordial gas-rich disks, which are the initial conditions of habitable planetary systems; and c) predicting the diverse characteristics of terrestrial planets based on the protoplanetary environments in which they are formed. We invite contributions from the astronomical, cosmochemical, astrochemical, and planetary science communities. The deadline for submission of abstracts is December 3, 2007. Authors will be notified of final abstract status by February 1, 2008. Instructions for registration and abstract submission can be found at the meeting website: http://abscicon.seti.org/

Jets from Young Stars I: Models and Constraints

Edited by Jonathan Ferreira, Catherine Dougados, Emma Whelan

Springer Lecture Notes in Physics Vol. 723

JETSET is a four year Marie Curie research training network on jet simulations, observations, experiments and theory. As part of a commitment to the training of young researchers, the training network has organised a number of schools covering areas relevant to the study of jet phenomena. This book "Jets from Young Stars I: Models and Constraints" is the first in a series that will be published by Springer. The first half of the book is devoted to general observational constraints, covering the outflow phenomenon in young stars, the identification of magneto-centrifugal processes as the main jet driving mechanism, and the magnetic interaction between the star and its accretion disc. The second half of the book is devoted to theoretical knowledge of magneto-hydrodynamic processes pertinent to the jet launching mechanism in young stars. This comprises a general introduction to magneto-hydrodynamics, a description of the role of MHD processes in Standard Accretion Discs, and the physics of steady state MHD outflows, from the basic concepts and equations to modern self-similar solutions. Further lectures detail the various classes of steady magnetic-wind models currently discussed in the context of protostellar jets.

The book contains the following articles based on the lectures given at the first JETSET school:

Part I: Observational Constraints

The First Three Million Years, *Tom Ray*
Jets from Young Stars: The Need for MHD Collimation and Acceleration Processes, *Sylvie Cabrit*
Star-disk Interaction in Classical T Tauri Stars, *Silvia Alencar*

Part II: Magneto-Hydrodynamic Models

Introduction to Magneto-Hydrodynamics, *Guy Pelletier*
Theory and Models of Standard Accretion Disks, *Caroline Terquem*
Theory of MHD Jets and Outflows, *Kanaris Tsinganos*
Transit Flows and Jet Asymptotics, *Thibaut Lery*
MHD Disc Winds, *Jonathan Ferreira*
Stellar Wind Models, *Christophe Sauty*

The second in the series of books "Jets from Young Stars II: Clues from High Angular Resolution Observations" is expected to be published by the end of the year. For further information please see www.springer.com or contact *ewhelan* at *cp.dias.ie*

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