

THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

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From the Editor

The Star Formation Newsletter started this month 13 years ago. In the intervening years it has steadily grown and has documented the remarkable developments that the field of star and planet formation has enjoyed in recent years. The original motivation for the Newsletter was the - at that time - exceedingly long time most journals took from a paper was accepted to it actually appeared in print. The Newsletter alerted readers to new preprints, which could be requested from the authors. The interval between acceptance and publication has been steadily decreasing, and at the same time electronic access to preprints has been vastly improving, with the emergence of Astro-Ph, and with many institutes having their own web pages with access to preprints. Now ADS also lists Astro-Ph preprints, increasing their visibility and accessibility. The question should therefore be asked whether the Star Formation Newsletter still has a role to play in our changing world of science. I have consulted with numerous colleagues, and the perhaps surprising answer seems to be that, yes, there is still a need for the Newsletter, but for a somewhat different reason than in the early days. It seems that while ease of access to the latest information is now well established, we are increasingly being overwhelmed with the sheer volume of information. The Newsletter offers a convenient and regular way to get an overview of the vast new literature in our field. However, for this function to be truly useful the Newsletter needs to be complete. So far, despite continuous efforts to get abstracts, the Newsletter has consistently missed about one third of the relevant literature. Henceforth, we will survey the web pages of the major journals (specifically AJ, ApJ, ApJS, A&A, MNRAS, Nature, Science, and Icarus), and include those abstracts of papers that have been accepted, but which were not sent to the Newsletter. The present issue is an experiment with this new format. Given the limited resources available for the Newsletter (essentially my own time with the help of a student, supported through a modest grant from the NASA Origins program), it is important that you continue to send your abstracts. If you for one or another reason fail to send your abstract, we will do our best to pick it up when it becomes available on the journal web pages. I hope that this new service does not lead to a decline in the number of submitted abstracts, since this could make the whole enterprise unmanageable. Finally, I have decided to no longer circulate the actual LaTeX file every month, but simply send out an e-mail with the URL of our web site, where you can pick up the latest Newsletter either as a LaTeX file, a postscript file, or a pdf file. Other formats may be added later.

Bo Reipurth

Abstracts of recently accepted papers

Extreme oxygen isotope ratios in the early Solar System

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The origins of the building blocks of the Solar System can be studied using the isotopic composition of early planetary and meteoritic material. Oxygen isotopes in planetary materials show variations at the per cent level that are not related to the mass of the isotopes; rather, they result from the mixture of components having different nucleosynthetic or chemical origins. Isotopic variations reaching orders of magnitude in minute meteoritic grains are usually attributed to stellar nucleosynthesis before the birth of the Solar System, whereby different grains were contributed by different stars. Here we report the discovery of abundant silica-rich grains embedded in meteoritic organic matter, having the most extreme $^{18}\text{O}/^{16}\text{O}$ and $^{17}\text{O}/^{16}\text{O}$ ratios observed (both $\sim 10^{-1}$) together with a solar silicon isotopic composition. Both O and Si isotopes indicate a single nucleosynthetic process. These compositions can be accounted for by one of two processes: a single exotic evolved star seeding the young Solar System, or irradiation of the circumsolar gas by high energy particles accelerated during an active phase of the young Sun. We favour the latter interpretation, because the observed compositions are usually not expected from nucleosynthetic processes in evolved stars, whereas they are predicted by the selective trapping of irradiation products.

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Modeling the Jovian subnebula: I. Thermodynamic conditions and migration of proto-satellites

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We have developed an evolutionary turbulent model of the Jovian subnebula consistent with the extended core accretion formation model of Jupiter. This model takes into account the vertical structure of the subnebula, as well as the evolution of the surface density as given by an α -disk model and is used to calculate the thermodynamical conditions in the subdisk for different values of the viscosity parameter. We show that the Jovian subnebula evolves in two different phases during its lifetime. In the first phase, the subnebula is fed through its outer edge by the solar nebula as long as it has not been dissipated. In the second phase, the solar nebula has disappeared and the Jovian subdisk expands and gradually clears with time as Jupiter accretes the remaining material. We also demonstrate that early generations of satellites formed during the beginning of the first phase of the subnebula cannot survive in this environment and fall onto the proto-Jupiter. As a result, these bodies may contribute to the enrichment of Jupiter in heavy elements. Moreover, migration calculations in the Jovian subnebula allow us to follow the evolution of the ices/rock ratios in the proto-satellites as a function of their migration pathways. By tempting to reproduce the distance distribution of the Galilean satellites, as well as their ices/rock ratios, we obtain some constraints on the viscosity parameter of the Jovian subnebula.

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A search for shock-excited optical emission from the outflows of massive young stellar objects

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We have searched for optical shock-excited emission lines in the outer parts of the bipolar outflows from massive young stellar objects where the flow terminates and the extinction is expected to be low. The Taurus Tunable Filter (TTF) at the Anglo-Australian Telescope (AAT) was used to obtain narrow-band ($12 - 15\text{\AA}$) images of the $H\alpha$, [NII] 6583, and [SII] 6717/6731 lines around Mon R2 IRS3, S255 IRS1/3, GL 961 and GL 989. No clear examples of shocked emission were found. A bow shock feature in the GL 989 region maybe related with the molecular outflow NGC 2264 D. A weak optical bow-like feature is seen in GL 961, but which of the stars in the cluster is the driving source cannot be uniquely identified. Other emission line features were found in Mon R2 and S255 that are consistent with an HII

region origin. The observed fluxes and the upper limits were compared with predictions from radiative shock models available in the literature. Any head-on collisions of a jet with speeds of the order of 500 km s^{-1} should have been detected if the extinction $A_V < 10$ mag. Estimates of the extinction in the outer parts of the molecular clouds are somewhat lower than this, although it is possible that it could be higher local to any interaction regions due to swept up material. If the extinction is low, then the shocks must either be slower ($\leq 150 \text{ km s}^{-1}$) or very oblique ($\geq 75^\circ$), which would argue against the presence of highly collimated jets from high mass young stellar objects.

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The Mass Spectra of Cores in Turbulent Molecular Clouds and Implications for the Initial Mass Function

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We investigate the core mass distribution (CMD) resulting from numerical models of turbulent fragmentation of molecular clouds. In particular we study its dependence on the sonic root-mean-square Mach number M_s . We analyze simulations with M_s ranging from 1 to 15 to show that, as M_s increases, the number of cores increases as well while their average mass decreases. This stems from the fact that high-Mach number flows produce many and strong shocks on intermediate to small spatial scales, leading to a highly-fragmented density structure. We also show that the CMD from purely turbulent fragmentation does not follow a single power-law, but it may be described by a function that changes continuously its shape, probably more similar to a log-normal function. The CMD in supersonic turbulent flows does not have a universal slope, and as consequence, cast some doubt on attempts to directly relate the CMD to a universal Initial Mass Function.

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<http://arxiv.org/abs/astro-ph/0509591>

Irradiated and Bent Jets in the Orion Nebula

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We present new images and proper motion measurements of irradiated outflows from young stars in the outskirts of the Orion Nebula obtained with the Advanced Camera for Surveys on-board the Hubble Space Telescope. The images reveal many new outflows and new details in previously detected flows. The large-scale bipolar flows such as HH 502, 505, 874, and 876 contain multiple shocks whose velocities systematically decrease with increasing distance from their sources as the flows bend away from the core of the Orion Nebula. We consider several mechanisms for bending jets, including radiation pressure, the rocket effect on a neutral jet, and the impact of a side-wind. While mild bends may be explained by either radiation pressure or the rocket effect, the extreme bends of some Orion's jets and LL Ori-type bow shocks are best explained by the interaction of these outflows with a large-scale flow from the nebular core. The jet $H\alpha$ emission measures and geometry are used to estimate their mass-loss rates which range from about $\dot{M} \sim 10^{-9}$ to $10^{-6} M_\odot \text{ yr}^{-1}$.

Many of the quasi-parabolic bow shocks that wrap around young stars in Orion (the LL Ori-type objects) exhibit large gaps between the observed jets and the parabolic fronts facing the core of the nebula. These may indicate the additional action of a wide-angle outflow component such as a T Tauri stellar wind, a proplyd photo-ablation flow, or possibly a photo-ablation flow from the jet itself. The $H\alpha$ surface brightness and radii of the LL Ori fronts are used to estimate that the $\dot{M}V_w$ products of the wide-angle flow components have values around $10^{-6} M_\odot \text{ yr}^{-1} \text{ kms s}^{-1}$. The side-wind density and velocity are also constrained. Outside the nebular core, the greatest concentration of bent

jets and LL Ori-type parabolic fronts are located south and west of the Trapezium. The non-uniform, clumpy spatial distribution of jets, outflow sources, and proplyds in the outskirts of the Orion Nebula indicate that star formation occurred in small hierarchical clusters.

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Ring shaped 6.7 GHz methanol maser emission around a young high-mass star

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We report on EVN imaging of the 6.7 GHz methanol maser emission from the candidate high-mass protostar G23.657–0.127. The masers originate in a nearly circular ring of 127 mas radius and 12 mas width. The ring structure points at a central exciting object which characteristics are typical for a young massive star; its bolometric luminosity is estimated to be $\leq 3.2 \times 10^4 L_{\odot}$ and $\leq 1.2 \times 10^5 L_{\odot}$ for near (5.1 kpc) and far (10.5 kpc) kinematic distances, respectively. However, the spatial geometry of the underlying maser region remains ambiguous. We consider scenarios in which the methanol masers originate in a spherical bubble or in a rotating disc seen nearly face-on.

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Preprint available at <http://arxiv.org/abs/astro-ph/0509578>

Submillimeter Array 440 μ m/690GHz line and continuum observations of Orion-KL

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Submillimeter Array observations of Orion-KL at $\sim 1''$ resolution in the 440 μ m/690 GHz band reveal new insights about the continuum and line emission of the region. The 440 μ m continuum flux density measurement from source *I* allows us to differentiate among the various proposed physical models: Source *I* can be well modeled by a “normal” protostellar SED consisting of a proton-electron free-free emission component at low frequencies and a strong dust component in the submillimeter bands. Furthermore, we find that the protostellar object SMA1 is clearly distinct from the hot core. The non-detection of SMA1 at cm and infrared wavelengths suggests that it may be one of the youngest sources in the entire Orion-KL region. The molecular line maps show emission mainly from the sources *I*, SMA1 and the hot core peak position. An analysis of the CH₃CN(37_K–36_K) *K*-ladder ($K = 0\dots3$) indicates a warm gas component of the order 600 ± 200 K. In addition, we detect a large fraction ($\sim 58\%$) of unidentified lines and discuss the difficulties of line identifications at these frequencies.

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

The first wide ultracool binary dwarf in the field: DENIS-J055146.0-443412.2 (M8.5 + L0)

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We present observations of a new very low mass field binary, discovered during an infrared imaging survey of 250 DENIS L and very late-M dwarfs. DENIS-J055146.0-443412.2 is an M8.5 + L0 pair, with a physical separation of over 200 AU. This makes it the widest very low mass binary known in the field, by an order of magnitude. Such a system is fragile, and it would not have survived a close encounter with a third body. Its existence demonstrates that some very low mass stars/brown dwarfs form without ejection from a multiple system, or any other strong dynamical interaction.

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Spiral shocks, triggering of star formation and the velocity dispersion in Giant Molecular Clouds

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We present numerical simulations of the passage of gas through a galactic spiral shock and the subsequent formation of giant molecular clouds (GMCs), and the triggering of star formation. In these simulations, we take account of the observed inhomogeneity, or clumpiness, of the pre-shock interstellar medium. As might be expected, the spiral shock forms dense clouds while dissipating kinetic energy, producing regions that are locally gravitationally bound and collapse to form stars. But the effect of the clumpiness of gas as it passes through the shock is to generate chaotic internal motions in the gas. The kinematics of these motions are found to agree with the observed velocity-dispersion/size relation found in star-forming regions. In contrast to the standard picture where continuously driven turbulence generates the density inhomogeneities in star-forming clouds, we find here that it is the clumpiness of the interstellar gas that produces the chaotic motions as it passes through the spiral shock and initiates the star formation process. The velocity dispersion can be understood as being due to the random mass loading of clumps as they converge in the spiral shock. Within these clouds both the timescale for the decay of these motions, and the timescale for forming stars, are comparable to the clouds' dynamical lifetimes. In this model there is no need for any internal or external continuous driving mechanism for the 'turbulence'. In addition, the coupling of the clouds' internal kinematics to their externally triggered formation removes the need for the clouds to be self-gravitating. Indeed, while clearly some parts of the clouds are self-gravitating and able to form stars, most of the molecular material remains gravitationally unbound. This can provide a simple explanation for the low efficiency of star formation.

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Discovery of a Low Mass Bipolar Molecular Outflow from L1014-IRS with the Submillimeter Array

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Using the Submillimeter Array we report the discovery of a compact low mass bipolar molecular outflow from L1014-IRS and confirm its association with the L1014 dense core at 200 pc. Consequently, L1014-IRS is the lowest luminosity ($L \sim 0.09L_{\odot}$) and perhaps the lowest mass source known to be driving a bipolar molecular outflow, which is one of the smallest known in size (~ 500 AU), mass ($< 10^{-4} M_{\odot}$), and energetics (e.g., force $< 10^{-7} M_{\odot} \text{ km s}^{-1} \text{ yr}^{-1}$).

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The origin and nature of Neptune-like planets orbiting close to solar type stars

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The sample of known exoplanets is strongly biased to masses larger than the ones of the giant gaseous planets of the Solar System. Recently, the discovery of two extrasolar planets of considerably lower masses around the nearby Stars GJ 436 and ρ Cancri was reported. They are like our outermost icy giants, Uranus and Neptune, but in contrast, these new planets are orbiting at only some hundredth of the Earth-Sun distance from their host stars, raising several new questions about their origin and constitution. Here we report numerical simulations of planetary accretion that show, for the first time through N-body integrations that the formation of compact systems of Neptune-like planets close to the hosts stars could be a common by-product of planetary formation. We found a regime of planetary accretion, in which orbital migration accumulates protoplanets in a narrow region around the inner edge of the nebula, where they collide each other giving rise to Neptune-like planets. Our results suggest that, if a protoplanetary solar environment is common in the Galaxy, the discovery of a vast population of this sort of 'hot cores' should be expected in the near future.

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Disks in Transition in the Taurus Population: *Spitzer* IRS Spectra of GM Aurigae and DM Tauri

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We present *Spitzer* Infrared Spectrograph (IRS) observations of two objects of the Taurus population that show unambiguous signs of clearing in their inner disks. In one of the objects, DM Tau, the outer disk is truncated at 3 AU; this object is akin to another recently reported in Taurus, CoKu Tau/4, in that the inner disk region is free of small dust. Unlike CoKu Tau/4, however, this star is still accreting, so optically thin gas should still remain in the inner disk region. The other object, GM Aur, also accreting, has ~ 0.02 lunar masses of small dust in the inner disk region within ~ 5 AU, consistent with previous reports. However, the IRS spectrum clearly shows that the optically thick outer disk has an inner truncation at a much larger radius than previously suggested, ~ 24 AU. These observations provide strong evidence for the presence of gaps in protoplanetary disks.

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Surface density of the young cluster IC 348 in the Perseus molecular cloud

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The IC 348 young star cluster contains more than 300 confirmed members. It is embedded in the Perseus molecular cloud, making any clustering analysis subject to an extinction bias. In this work, we derive the extinction map of the cloud and revisit the content of IC 348 through a statistical approach that uses the 2MASS data. Our goal was to address the question of the completeness of IC 348 and of young clusters in general. We performed a combined analysis of the star color and density in this region, in order to establish the surface density map of the cluster. We reached the conclusion that IC 348 has structures up to 25' from the cluster center, and we estimate that about 40 members brighter than $K_s = 13$ mag are still unidentified. Although we cannot use our statistical method to identify these new members individually, the surface density map gives a strong indication of their actual location. They are distributed in the outer regions of the cluster, where very few dedicated observations have been made so far, which is probably why they escaped previous identification. In addition, we propose the existence of a new embedded cluster associated to the infrared source MSX6C G160.2784-18.4216, about 38' south of IC 348.

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Grain Alignment by Radiation in Dark Clouds and Cores

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We study alignment of grains by radiative torques. We found a steep rise in radiative torque efficiency as grain size increases. This allows the larger grains that are known to exist within molecular clouds to be aligned by the attenuated and reddened interstellar radiation field. In particular, we found that, even deep inside giant molecular clouds, e.g., at optical depths corresponding to $A_V \leq 10$, large grains can still be aligned by radiative torques. This means that, contrary to earlier claims, far-infrared/submillimeter polarimetry provides a reliable tool to study magnetic fields of prestellar cores. Our results show that the grain size distribution is important for determining the relation between the degree of polarization and intensity.

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Transit flow models for low and high mass protostars

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In this work, the gas infall and the formation of outflows around low and high mass protostars are investigated. A radial self-similar approach to model the transit of the molecular gas around the central object is employed. We include gravitational and radiative fields to produce heated pressure-driven outflows with magneto-centrifugal acceleration and collimation. Outflow solutions with negligible or vanishing magnetic field are reported. They indicate that thermodynamics is a sufficient engine to generate an outflow. The magnetized solutions show dynamically significant differences in the axial region, precisely where the radial velocity and collimation are the largest. They compare quantitatively well with observations. The influence of the opacity on the transit solutions is also studied. It is found that, when dust is not the dominant coolant, such as in the primordial universe, mass infall rates have substantial larger values in the equatorial region. This suggests that star forming in a dust-free environment should be able to accrete much more mass and become more massive than present day protostars. It is also suggested that molecular outflows may be dominated by the global transit of material around the protostar during the very early stages of star formation, especially in the case of massive or dust-free star formation.

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Centimeter emission in the UY Aur System

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We report 3.6 cm continuum observations taken with the Very Large Array (VLA) of the young binary system UY Aur. The binary consists of a T Tauri star, UY Aur A, and a so-called “infrared companion” (IRC), UY Aur B, separated by 0.89". UY Aur is an interesting system because it shows observational features whose origin is not well understood. One of them is the unusual low spectral index found in the millimeter region. In our VLA study, we have detected centimeter continuum radiation that coincides with the reported positions at 1.3 and 2.7 mm and is consistent with the optical position of UY Aur. We conclude that the 3.6 cm emission is associated with the binary system. Furthermore, we suggest that the centimeter emission might be related to a previously reported bipolar outflow.

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see astro-ph for preprint

The CORALIE survey for southern extra-solar planets: XIII. A pair of planets around HD 202206 or a circumbinary planet?

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Long-term precise Doppler measurements with the CORALIE spectrograph reveal the presence of a second planet orbiting the solar-type star HD 202206. The radial-velocity combined fit yields companion masses of $m_2 \sin i = 17.4 M_{Jup}$ and $2.44 M_{Jup}$, semi-major axes of $a = 0.83$ AU and 2.55 AU, and eccentricities of $e = 0.43$ and 0.27 , respectively. A dynamical analysis of the system further shows a 5/1 mean motion resonance between the two planets. This system is of particular interest since the inner planet is within the brown-dwarf limits while the outer one is much less massive. Therefore, either the inner planet formed simultaneously in the protoplanetary disk as a *superplanet*, or the outer *Jupiter-like* planet formed in a circumbinary disk. We believe this singular planetary system will provide important constraints on planetary formation and migration scenarios.

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The Radial Velocity Distribution of Class I and Flat-Spectrum Protostars

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We analyze radial velocities for a sample of 31 Class I and flat spectrum protostars in Taurus-Auriga, rho Ophiuchi and Serpens for evidence of the global dynamical state of extremely young stellar populations buried within parental molecular clouds. Comparing the radial velocity of each protostar to that of the local CO gas, we are able to constrain the one dimensional radial velocity dispersion of Class I and flat spectrum objects to ~ 2.5 km/sec or below. This upper limit to the protostellar velocity dispersion is consistent with the velocity dispersions of surrounding CO gas which we

measure to be ~ 1.4 km/sec, suggesting that the motions of protostars and local CO gas are dynamically linked and dominated by the gravitational potential of the molecular cloud. However, the upper limit on the protostellar velocity dispersion could still allow for slightly inflated motions of protostars relative to the local molecular gas. Four of the protostars analyzed appear to have velocities more than 3σ (7.5 km/sec) away from the central local CO gas velocity while showing spectroscopic indicators of youth and accretion such as H₂ emission, HI Br Gamma emission, or K band continuum veiling. These radial velocity outliers may represent protostellar spectroscopic binaries or ejected cluster members.

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Dynamical and chemical properties of the "starless" core L1014

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Spitzer Space Telescope observations of a point-like source, L1014-IRS, close to the dust peak of the low-mass dense core L1014, have raised questions about its starless nature. These show the presence of an object with colors expected for an embedded protostar with the implication that L1014-IRS would be the lowest luminosity isolated protostar known, and an ideal target with which to test star formation theories at the low mass end.

In order to study its molecular content and to search for the presence of a molecular outflow, we mapped L1014 in at least one transition of ¹²CO, N₂H⁺, HCO⁺, CS, and of their isotopologues ¹³CO, C¹⁸O, C¹⁷O, N₂D⁺, and H¹³CO⁺, using the Five College Radio Astronomy Observatory (FCRAO), the IRAM 30 m antenna, and the Caltech Submillimeter Observatory (CSO). The data show physical and chemical properties in L1014 typical of *moderately evolved* dense cores: i.e. H₂ central density of a few 10⁵ molecules cm⁻³, estimated mass of $\sim 2M_{\odot}$, CO integrated depletion factor less than 10, $N(N_2H^+)/6 \times 10^{12} \text{cm}^{-2}$, $N(N_2D^+)/N(N_2H^+)$ equal to 10%, and relatively broad N₂H⁺ and N₂D⁺ lines (0.35 km s⁻¹). Infall signatures and significant velocity shifts between optically thick and optically thin tracers are not observed in the line profiles.

No classical signatures of molecular outflow are found in the ¹²CO and ¹³CO FCRAO observations. In particular, no high velocity wings are found, and no well-defined blue-red lobes of ¹²CO emission are seen in the channel maps. Sensitive, higher resolution observations will clarify the presence of a molecular outflow on a smaller scale than that probed by our observations.

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Wide-Angle Wind-driven Bipolar Outflows: High-Resolution Models with Application to Source I of the Becklin-Neugebauer/Kleinmann-Low OMC-I Region

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We carry out high-resolution simulations of the inner regions of a wide-angle wind-driven bipolar outflow using an adaptive mesh refinement code. Our code follows H-He gas with molecular, atomic, and ionic components and the associated time-dependent molecular chemistry and ionization dynamics with radiative cooling. Our simulations explore the nature of the outflow when a spherical wind expands into a rotating, collapsing envelope. We compare

these with key observational properties of the outflow system of source I in the BN/KL region. Our calculations show that the wind evacuates a bipolar outflow cavity in the infalling envelope. We find the head of the outflow to be unstable and that it rapidly fragments into clumps. We resolve the dynamics of the strong shear layer, which defines the side walls of the cavity. We conjecture that this layer is the likely site of maser emission and examine its morphology and rotational properties. The shell of swept-up ambient gas that delineates the cavity edge retains its angular momentum. This rotation is roughly consistent with that observed in the source I SiO maser spots. The observed proper motions and line-of-sight velocity are approximately reproduced by the model. The cavity shell at the base of the flow assumes an X-shaped morphology that is also consistent with source I. We conclude that the wide opening angle of the outflow is evidence that a wide-angle wind drives the source I outflow and not a collimated jet.

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First determination of the (re)crystallization activation energy of an irradiated olivine-type silicate

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To study the evolution of silicate dust in different astrophysical environments we simulate, in the laboratory, interstellar and circumstellar ion irradiation and thermal annealing processes. An experimental protocol that follows different steps in the dust life-cycle was developed. Using the silicate 10 μm band as an indicator, the evolution of the structural properties of an ion-irradiated olivine-type silicate sample, as a function of temperature, is investigated and an activation energy for crystallization is determined. The obtained value of $E_a/k = 41700 \pm 2400\text{K}$ is in good agreement with previous determinations of the activation energies of crystallization reported for non-ion-irradiated, amorphous silicates. This implies that the crystallization process is independent of the history of the dust. In particular, the defect concentration due to irradiation appears not to play a major role in stimulating, or hindering, crystallization at a given temperature. This activation energy is an important thermodynamical parameter that must be used in theoretical models which aim to explain the dust evolution from its place of birth in late type stars to its incorporation into young stellar environments, proto-stellar discs and proto-planetary systems after long passage through the interstellar medium.

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The INT Photometric H α Survey of the Northern Galactic Plane (IPHAS)

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The Isaac Newton Telescope (INT) Photometric H α Survey of the Northern Galactic Plane (IPHAS) is a 1800-deg² CCD survey of the northern Milky Way spanning the latitude range $-5^\circ < b < +5^\circ$ and reaching down to $r' \simeq 20(10\sigma)$. Representative observations and an assessment of point-source data from IPHAS, now underway, are presented. The data obtained are Wide Field Camera images in the H α narrow-band, and Sloan r' and i' broad-band filters. We simulate IPHAS ($r' - H\alpha$, $r' - i'$) point-source colours using a spectrophotometric library of stellar spectra and available filter transmission profiles: this defines the expected colour properties of (i) solar metallicity stars, without H α emission, and (ii) emission-line stars. Comparisons with observations of fields in Aquila show that the simulations of normal star colours reproduce the observations well for all spectral types earlier than M. A further comparison between colours synthesized from long-slit flux-calibrated spectra and IPHAS photometry for six objects in a Taurus field confirms the reliability of the pipeline calibration. Spectroscopic follow-up of a field in Cepheus shows that sources lying above the main stellar locus in the ($r' - H\alpha$, $r' - i'$) plane are confirmed to be emission-line objects with very few failures. In this same field, examples of H α deficit objects (a white dwarf and a carbon star) are shown to be readily distinguished by their IPHAS colours. The role IPHAS can play in studies of spatially resolved northern Galactic nebulae is discussed briefly and illustrated by a continuum-subtracted mosaic image of Shajn 147 (a supernova remnant, 3 $^\circ$ in diameter). The final catalogue of IPHAS point sources will contain photometry on about 80 million objects. Used on its own, or in combination with near-infrared photometric catalogues, IPHAS is a major resource for the study of stellar populations making up the disc of the Milky Way. The eventual yield of new northern emission-line objects from IPHAS is likely to be an order of magnitude increase on the number already known.

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Methanol masers : Reliable tracers of the early stages of high-mass star formation

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The *GLIMPSE* and *MSX* surveys have been used to examine the mid-infrared properties of a statistically complete sample of 6.7 GHz methanol masers. The *GLIMPSE* point sources associated with methanol masers are clearly distinguished from the majority, typically having extremely red mid-infrared colors, similar to those expected of low-mass class 0 young stellar objects. The intensity of the *GLIMPSE* sources associated with methanol masers is typically 4 magnitudes brighter at 8.0 μm than at 3.6 μm . Targeted searches towards *GLIMPSE* point sources with $[3.6]-[4.5] > 1.3$ and an 8.0 μm magnitude less than 10 will detect more than 80% of class II methanol masers. Many of the methanol masers are associated with sources within infrared dark clouds (IRDC) which are believed to mark regions where high-mass star formation is in its very early stages. The presence of class II methanol masers in a significant fraction of IRDC suggests that high-mass star formation is common in these regions. Different maser species are thought to trace different evolutionary phases of the high-mass star formation process. Comparison of the properties of the *GLIMPSE* sources associated with class II methanol masers and other maser species shows interesting trends, consistent with class I methanol masers tracing a generally earlier evolutionary phase and OH masers tracing a later evolutionary phase.

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The Effect of Star Formation History on the Inferred Initial Stellar Mass Function

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Peaks and lulls in the star formation rate (SFR) over the history of the Galaxy produce plateaux and declines in the present day mass function (PDMF) where the main-sequence lifetime overlaps the age and duration of the SFR variation. These PDMF features can be misinterpreted as the form of the intrinsic stellar initial mass function (IMF) if the star formation rate is assumed to be constant or slowly varying with time. This effect applies to all regions that have formed stars for longer than the age of the most massive stars, including OB associations, star complexes, and especially galactic field stars. Related problems may apply to embedded clusters. Evidence is summarized for temporal SFR variations from parsec scales to entire galaxies, all of which should contribute to inferred IMF distortions. We give examples of various star formation histories to demonstrate the types of false IMF structures that might be seen. These include short-duration bursts, stochastic histories with log-normal amplitude distributions, and oscillating histories with various periods and phases. The inferred IMF should appear steeper than the intrinsic IMF over mass ranges where the stellar lifetimes correspond to times of decreasing SFRs; shallow portions of the inferred IMF correspond to times of increasing SFRs. If field regions are populated by dispersed clusters and defined by their low current SFRs, then they should have steeper inferred IMFs than the clusters. The SFRs required to give the steep field IMFs in the LMC and SMC are determined. Structure observed in several determinations of the Milky Way field star IMF can be accounted for by a stochastic and bursty star formation history.

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Bolocam Survey for 1.1 mm Dust Continuum Emission in the c2d Legacy Clouds. I. Perseus

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We have completed a 1.1 mm continuum survey of 7.5 deg² of the Perseus Molecular Cloud using Bolocam at the Caltech Submillimeter Observatory. This represents the largest millimeter or submillimeter continuum map of Perseus to date. Our map covers more than 30,000 31" (FWHM) resolution elements to a 1 σ RMS of 15 mJy/beam. We detect a total of 122 cores above a 5 σ point source mass detection limit of 0.18 M_{\odot} , assuming a dust temperature of $T_D = 10$ K, 60 of which are new millimeter or submillimeter detections. The 1.1 mm mass function is consistent with a broken power law of slope $\alpha_1 = 1.3$ ($0.5M_{\odot} < M < 2.5M_{\odot}$) and $\alpha_2 = 2.6$ ($M > 2.5M_{\odot}$), similar to the local initial mass function slope ($\alpha_1 = 1.6$ $M < 1M_{\odot}$, $\alpha_2 = 2.7$ $M > 1M_{\odot}$). No more than 5% of the total cloud mass is contained in discrete 1.1 mm cores, which account for a total mass of 285 M_{\odot} . We suggest an extinction threshold for millimeter cores of $A_V \sim 5$ mag, based on our calculation of the probability of finding a 1.1 mm core as a function of A_V . Much of the cloud is devoid of compact millimeter emission; despite the significantly greater area covered compared to previous surveys, only 5 – 10 of the newly identified sources lie outside previously observed areas. The two-point correlation function confirms that dense cores in the cloud are highly structured, with significant clustering on scales as large as 2×10^5 AU. Our 1.1 mm emission survey reveals considerably denser, more compact material than maps in other column density tracers such as ¹³CO and A_V , although the general morphologies are roughly consistent. These 1.1 mm results, especially when combined with recently acquired c2d Spitzer Legacy data, will provide a census of dense cores and protostars in Perseus and improve our understanding of the earliest stages of star formation in

molecular clouds.

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Full-Polarization Observations of OH Masers in Massive Star-forming Regions. I. Data

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We present full-polarization VLBA maps of the ground-state, main-line, $^2P_{3/2}$, $J = 3/2$ OH masers in 18 Galactic massive star-forming regions. This is the first large polarization survey of interstellar hydroxyl masers at VLBI resolution. A total of 184 Zeeman pairs are identified, and the corresponding magnetic field strengths are indicated. We also present spectra of the NH_3 emission or absorption in these star-forming regions. Analysis of these data will be presented in a companion paper.

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Oligarchic and giant impact growth of terrestrial planets in the presence of gas giant planet migration

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Giant planets found orbiting close to their central stars, the so-called "hot Jupiters", are thought to have originally formed in the cooler outer regions of a protoplanetary disk and then to have migrated inward via tidal interactions with the nebula gas. We present the results of N-body simulations which examine the effect such gas giant planet migration has on the formation of terrestrial planets. The models incorporate a 0.5 Jupiter mass planet undergoing type II migration through an inner protoplanet-planetesimal disk, with gas drag included. Each model is initiated with the inner disk being at successively increased levels of maturity, so that it is undergoing either oligarchic or giant impact style growth as the gas giant migrates.

In all cases, a large fraction of the disk mass survives the passage of the giant, either by accreting into massive terrestrial planets shepherded inward of the giant, or by being scattered into external orbits. Shepherding is favored in younger disks where there is strong dynamical friction from planetesimals and gas drag is more influential, whereas scattering dominates in more mature disks where dissipation is weaker. In each scenario, sufficient mass is scattered outward to provide for the eventual accretion of a set of terrestrial planets in external orbits, including within the system's habitable zone. This scattering, however, significantly reduces the density of solid material, indicating that further accretion will occur over very long time scales. A particularly interesting result is the generation of massive, short period, terrestrial planets from compacted material pushed ahead of the giant. These planets are reminiscent of the short period Neptune-mass planets discovered recently, suggesting that such "hot Neptunes" could form locally as a by-product of giant planet migration.

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XMM-Newton observations of the σ Ori cluster. II. Spatial and spectral analysis of the full EPIC field

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We present the results of an XMM-Newton observation of the young ($\sim 2 - 4$ Myr) cluster around the hot star σ Orionis. In a previous paper we presented the analysis of the RGS spectrum of the central hot star; here we discuss the results of the analysis of the full EPIC field. We have detected 175 X-ray sources, 88 of which have been identified with cluster members, including very low-mass stars down to the substellar limit. We detected also eleven new possible candidate members from the 2MASS catalogue. We find that late-type stars have a median $\log L_X/L_{\text{bol}} \sim -3.3$, i.e. very close to the saturation limit. We detected significant variability in $\sim 40\%$ of late-type members or candidates, including 10 flaring sources; rotational modulation is detected in one K-type star and possibly in other 3 or 4 stars. Spectral analysis of the brightest sources shows typical quiescent temperatures in the range $T_1 \sim 0.3 - 0.8$ keV and $T_2 \sim 1 - 3$ keV, with subsolar abundances $Z \sim 0.1 - 0.3 Z_\odot$, similarly to what is found in other star-forming regions and associations. We find no significant difference in the spectral properties of classical and weak-lined T Tauri stars, although classical T Tauri stars tend to be less X-ray luminous than weak-lined T Tauri stars

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Ambipolar diffusion in self-gravitating filaments

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One-dimensional similarity solutions for a collapsing, homogeneous, infinitely long cylinder that is subject to ambipolar diffusion are given. There is an analytical solution with infinite density being reached after 4.3 free-fall times. In that case the magnetic field strength B_z on the axis scales like $B_z \propto \rho^{2/3}$ with density ρ . The analytical solution proves "attractive". Even if the initial conditions depart slightly from those of the analytical solution, that solution is nevertheless approached through damped oscillations.

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On the accumulation of solid bodies in global turbulent protoplanetary disc models

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We study the migration of solid bodies in turbulent protoplanetary accretion discs by means of global MHD simulations. The bodies range in size from 5 centimetres up to 1 metre, and so include objects whose migration is expected to be the most rapid due to gas drag interaction with the disc. As they drift inward through the disc, some of them are trapped in regions where gas pressure maxima are created by long lived anticyclonic vortices. This accumulation is very efficient, locally increasing the dust-to-gas ratio by a factor ζ 100 in some cases. We discuss the possible implications of this result for theories of planet formation.

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The veiling spectrum of DI Cep and its relationship to emission line profiles

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High spectral resolution variability studies of classical T Tauri stars (CTTS) are an essential instrument for probing the physical conditions and dynamics of their atmospheres and immediate vicinity. The shapes of the excess continuum

emission and of the line profiles, their variability and relationship are all crucial tools to achieve that goal. We use high spectral resolution optical data of the CTTS DI Cep to suggest a new diagnostic tool to investigate the relationship between the line emission/absorption and the excess continuum emission. By correlating the veiling continuum to the line flux in discrete velocity bins across the emission line we obtain a correlation profile, from which one can discriminate between parts of the line that relate differently to the veiling. An earlier report of an unexpected hump around 5300 Å in the continuum excess emission spectrum of a couple of CTTS is not explained by current models of those stars. We identified a similar feature in the veiling spectrum of DI Cep and discuss, in this context, the relevance of the broad photospheric absorption features present in the spectra of late-type stars. Regarding DI Cep, we find that its radial velocity seems to be variable but no significant periodicity could be derived, possibly due to inadequate time sampling. We argue that this CTTS is most probably observed nearly equator on. Accretion flows could not be identified directly in the emission lines, but their presence is inferred from the analysis of the veiling spectrum, which yields typical projected accretion rates around $2.5 \times 10^{-7} M_{\odot} \text{ yr}^{-1}$.

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First Ultraviolet Spectrum of a Brown Dwarf: Evidence for H₂ Fluorescence and Accretion

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We analyze an HST STIS ultraviolet spectrum of the young brown dwarf 2MASSW J1207334-393254, a member of the 10 million year old TW Hya association that has a planetary-mass companion. We detect and identify numerous emission lines. C IV and other ions are seen that arise in hot gas. We identify a series of lines with Lyman-pumped H₂ molecular lines, indicating that cool gas is also present. Overall, this substellar object shows many of the same characteristics as classical T Tauri stars. We interpret our results as direct evidence of accretion from a circumstellar gas disk, consistent with previous claims. The lack of Si IV emission from the accreting gas indicates that silicon has been depleted into grains.

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Tracing the base of protostellar wind(s) towards the high-mass star forming region AFGL 5142: VLA continuum and VLBA water maser observations

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We have conducted phase-reference multi-epoch observations of the 22.2 GHz water masers using the Very Long Baseline Array (VLBA) and multi-frequency study of the continuum emission using the Very Large Array (VLA) towards the high-mass star forming region (SFR) AFGL 5142. 29 maser features were identified and most of them were persistent over the four observing epochs, allowing *absolute* proper motions to be determined. The water maser emission comes from two elongated structures (indicated as Group I and Group II), with the measured proper motions aligned along the structures' elongation axes. Each group consists of two (blue- and red-shifted) clusters of features separated by a few hundreds and thousands of AU respectively for Group I and Group II.

The maser features of Group II have both positions and velocities aligned along a direction close to the axis of the outflow traced by HCO⁺ and SiO emission on angular scales of tens of arcsec. We predict that the maser emission arises from dense, shocked molecular clumps displaced along the axis of the **molecular outflow**. The two maser clusters of Group I are oriented on the sky along a direction forming a large angle ($> 60^\circ$) with the axis of the jet/outflow traced by Group II maser features. We have detected a compact (8.4 and 22 GHz) continuum source (previously reported at 4.9 and 8.4 GHz) that falls close to the centroid of Group I masers, indicating that the source ionizing the gas is also responsible for the excitation of the water masers. The kinematic analysis indicates that the Group I masers trace outflowing rather than rotating gas, discarding the Keplerian disk scenario proposed in a previous paper for Group I. Since the axis joining the two maser clusters of Group II does not cross the position of the continuum source, Group II masers might be excited by an (undetected) massive YSO, distinct from the one (pinpointed by the VLA continuum

emission) responsible for the excitation of the Group I masers.

Our results give support to models of accretion and jet ejection related to the formation of high-mass stars.

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On the source of dense outflows from T Tauri stars II. Warm disc winds

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Recent ultraviolet (UV) observations suggest that there is a hot ($T_e \simeq 80000$ K) and dense ($N_e \simeq 10^{10} \text{cm}^3$) wind associated with the large-scale jets observed in classical T Tauri stars (cTTs). The observations of these rather evolved sources cannot be fitted with the classical cold disc wind solutions. This is not unexpected since the accretion rates are moderate ($\leq 10^{-8} M_\odot \text{yr}^{-1}$) and the wind lighter than at earlier phases. Henceforth, X-ray radiation from the star and the stardisc interaction region is expected to modify the thermal structure of the inner disc, e.g. the base of the disc wind. Thus, thermal pressure is relevant to load gas on the field lines. In this work, we analyse whether warm disc winds can account for these UV observations.

To get a good hint on the physics, we have preferred to focus on analytical work. We have made use of the warm disc wind solution with pressure calculated by Vlahakis et al. The rich complexity of the magnetohydrodynamic (MHD) disc wind kinematics is analysed in detail. We show the following. (i) *Warm disc flows* departing from the inner disc radius (~ 0.1 au) reach terminal velocities close to the observed (300 km s^{-1}) and that the temperature at the base of the wind is $\simeq 40000$ K. Thus, the spectral signature of *warm disc winds* is an enhancement of the chromospheric and transition region spectral indicators by several orders of magnitude, as observed in cTTs. (ii) *Warm disc winds* rotate, but their rotation velocity is small since the wind dynamics is based in a transference of angular momentum from the star to the magnetic field. Henceforth, slow rotation plus high temperature (e.g. rotational broadening) show in very broad profiles at the base of the wind. (iii) The kinematics at the base of the wind is dominated by *axial expansion*; however, above $z \simeq 5$ au, the dominant kinematical component is acceleration along the disc axis. (iv) The most often observed profile is a single-peaked line, slightly blueshifted and asymmetric with a tail to short wavelengths. The full width at half-maximum is clearly suprathreshold and depends on the spectral tracer used.

Line profiles, fluxes and line ratios are calculated for the C IV[uv1], C III]₁₉₀₈, C II]₂₃₂₆, Si III]₁₈₉₂ and [O II]₂₄₇₁ UV lines. In edge-on systems, the profiles range from symmetric lines with suprathreshold broadenings for the spectral tracers of the base of the wind (C IV[uv1] and Si III]₁₈₉₂) to double-peaked profiles for spectral tracers more weighted to higher values of z ([O II] and C II]). In pole-on systems, the profiles are blueshifted (from few to 200 km s^{-1}) and asymmetric exhibiting long tails towards the terminal velocity of the wind ($V_{rad} = 300 \text{ km s}^{-1}$). To reproduce the observed line fluxes and ratios, winds must be clumpy and extinction by the flaring disc and the wind itself ought to be taken into account.

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Coronagraphic Imaging of PreMain-Sequence Stars with the Hubble Space Telescope Space Telescope Imaging Spectrograph. I. The Herbig Ae Stars

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STIS white-light coronagraphic imaging has been carried out for 14 nearby, lightly reddened Herbig Ae stars, providing data on the environments and disks associated with these stars. No disks are detected in our data when the Herbig Ae star is accompanied by a stellar companion at $r \leq 2''$. We find that the optical visibility of protoplanetary disks associated with Herbig Ae stars at $r \geq 50$ -70 AU from the star is correlated with the strength of the mid-IR PAH features, particularly $6.2 \mu\text{m}$. These features, like the FUV fluorescent H_2 emission, trace the presence of material sufficiently far above the disk midplane that it is directly illuminated by the star's FUV radiation. In contrast, measures of the bulk properties of the disk, including ongoing accretion activity, mass, and the submillimeter slope of the SED, do not correlate with the surface brightness of the optical nebulosity. Modelers have interpreted the appearance of the IR SED and the presence of emission from warm silicate grains at $10 \mu\text{m}$ as a measure of geometrical shadowing by material in the disk near the dust sublimation radius of 0.5 AU. Geometrical shadowing sufficient to render a disk dark to distances as large as 500 AU from a star would require that the star be optically visible only if viewed essentially pole-on, in disagreement with our program star system inclinations. Rather than invoking shadowing to account for the optically dark disks, the correlation of the STIS detections with PAH emission features suggests a correlation with disk flaring and an anticorrelation with the degree of dust settling toward the midplane. If this correlation continues to lower levels, the STIS data suggest that improvements in coronagraph performance that suppress the residual scattered and diffracted stellar light by an additional factor of ≥ 10 should render the majority of disks associated with nearby Herbig Ae stars detectable.

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17 new very low-mass members in Taurus. The brown dwarf deficit revisited.

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Recent studies of the substellar population in the Taurus cloud have revealed a deficit of brown dwarfs compared to the Trapezium cluster population. However, these works have concentrated on the highest stellar density regions of the Taurus cloud. We have performed a large scale optical survey of this region, covering a total area of $\simeq 28 \text{ deg}^2$, and encompassing the densest parts of the cloud as well as their surroundings, down to a mass detection limit of 15 M_J . We present the optical spectroscopic follow-up observations of 97 photometrically selected potential new low-mass Taurus members, of which 27 are strong late-M spectral type ($SpT \geq M4V$) candidates. Our spectroscopic survey is 87 % complete down to $i' = 20$ for spectral types later than M4V, which corresponds to a mass completeness limit of 30 M_J for ages ≤ 10 Myr and $A_v \leq 4$. We derive spectral types, visual absorption and luminosity class estimates and discuss our criteria to assess Taurus membership. These observations reveal 5 new VLM Taurus members and 12 new BDs. Two of the new VLM sources and four of the new substellar members exhibit accretion/outflow signatures similar to higher mass classical T Tauri stars. From levels of $\text{H}\alpha$ emission we derive a fraction of accreting sources of 42 % in the substellar Taurus population. Combining our observations with previously published results, we derive an updated substellar to stellar ratio in Taurus of $\mathcal{R}_{ss} = 0.23 \pm 0.05$. This ratio now appears consistent with the value previously derived in the Trapezium cluster under similar assumptions of 0.26 ± 0.04 . indications that the relative

numbers of BDs with respect to stars is decreased by a factor 2 in the central regions of the aggregates with respect to the more distributed population. Our findings are best explained in the context of the *embryo-ejection model* where brown dwarfs originate from dynamical interactions in small N unstable multiple systems.

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Growth and sedimentation of dust particles in the vicinity of local pressure enhancements in a solar nebula

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A planet-forming nebula is a dynamic environment whose properties and structure vary with time. At the early stage of planet formation, when small grains coagulate to form larger objects, the dynamics of such an environment and its time-varying structure have considerable effects on that process. Among such structures, regions where the pressure of the gas is locally enhanced are of particular interest. In the vicinity of these regions, the combined effect of gas drag and pressure gradients, which in a nebula with a monotonic pressure gradient creates gas drag-induced migration of solids towards the central star causes solid particles to migrate inward/outward, and accumulate at the location of the pressure-enhanced region. While migrating, solid particles sweep up smaller objects and grow in size. In this paper, the effects of the appearance of pressure-enhanced structures on the growth and sedimentation of micron-sized particles are studied, and the effects of gas drag and pressure gradients on the rate of accumulation of centimetre-sized objects in the regions of local maximum pressure on the midplane are discussed. To portray a more detailed picture of the dynamical influence of such structures on the motions and interactions of particles, comparisons are made with the results of similar studies in a nebula without pressure-enhanced structures, and the cases, in which the changes in the physical properties of the gas and particles will enhance the growth rates of solids, are discussed. A discussion is also presented on the inelastic collision of dust particles and the corrections to the formulae of sticking velocity that currently exist in the literature.

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Detection of X-ray emission from β Pictoris with XMM-Newton: a cool corona, a boundary layer or what?

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β Pictoris (HR 2020) is the most prominent prototype of stars with circumstellar disks and has generated particular interest in the framework of young planetary systems. Given its spectral type A5, stellar activity is not expected. Nevertheless, resonance lines of C III and O VI typical for a chromosphere and transition region have been unambiguously detected with FUSE. We present results from an XMM-Newton observation of β Pic and find evidence for X-ray emission. In particular, we detected an emission of O VII at 21.6 Å with the MOS detectors. These findings present a challenge for the development of both stellar activity and disk models. We discuss and investigate various models to explain the observed emission including the presence of a cool corona and a boundary layer.

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Formation and Evolution of Planetary Systems: Upper Limits to the Gas Mass in HD 105

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We report infrared spectroscopic observations of HD 105, a nearby (~ 40 pc) and relatively young (~ 30 Myr) G0 star with excess infrared continuum emission, which has been modeled as arising from an optically thin circumstellar dust disk with an inner hole of size ≥ 13 AU. We have used the high spectral resolution mode of the Infrared Spectrometer (IRS) on the *Spitzer Space Telescope* to search for gas emission lines from the disk. The observations reported here provide upper limits to the fluxes of H₂S(0) 28 μ m, H₂S(1) 17 μ m, H₂S(2) 12 μ m, [Fe II] 26 μ m, [Si II] 35 μ m, and [S I] 25 μ m infrared emission lines. The H₂ line upper limits place direct constraints on the mass of warm molecular gas in the disk: $M(\text{H}_2) \leq 4.6, 3.8 \times 10^{-2},$ and $3.0 \times 10^{-3} M_J$ at $T = 50, 100,$ and 200 K, respectively. We also compare the line flux upper limits to predictions from detailed thermal/chemical models of various gas distributions in the disk. These comparisons indicate that if the gas distribution has an inner hole with radius $r_{i,gas}$, the surface density at that inner radius is limited to values ranging from mg cm^{-2} at $r_{i,gas} = 0.5$ AU to 0.1 g cm^{-2} at $r_{i,gas} = 5\text{-}20$ AU. These values are considerably below the value for a minimum mass solar nebula, and suggest that less than 1 Jupiter mass (M_J) of gas (at any temperature) exists in the 1-40 AU planet-forming region. Therefore, it is unlikely that there is sufficient gas for gas giant planet formation to occur in HD 105 at this time.

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Accretion of the Gaseous Envelope of Jupiter around a 5 – 10 Earth–Mass Core

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New numerical simulations of the formation and evolution of Jupiter are presented. The formation model assumes that first a solid core of several M_{\oplus} accretes from the planetesimals in the protoplanetary disk, and then the core captures a massive gaseous envelope from the protoplanetary disk. Earlier studies of the core accretion - gas capture model (Pollack et al. 1996, *Icarus* 124, 62) demonstrated that it was possible for Jupiter to accrete with a solid core of 10 to 30 M_{\oplus} in a total formation time comparable to the observed lifetime of protoplanetary disks. Recent interior models of Jupiter and Saturn that agree with all observational constraints suggest that Jupiter's core mass is 0 – 11 M_{\oplus} and Saturn's is 9 – 22 M_{\oplus} (Saumon and Guillot 2004, *Astrophys. J.* 609, 1170). We have computed simulations of the growth of Jupiter using various values for the opacity produced by grains in the protoplanet's atmosphere and for the initial planetesimal surface density, $\sigma_{init,Z}$, in the protoplanetary disk. We also explore the implications of halting the solid accretion at selected core mass values during the protoplanet's growth. Halting planetesimal accretion at low core mass simulates the presence of a competing embryo, and decreasing the atmospheric opacity due to grains emulates the settling and coagulation of grains within the protoplanet's atmosphere. We examine the effects of adjusting these parameters to determine whether or not gas runaway can occur for small mass cores on a reasonable timescale.

We compute four series of simulations with the latest version of our code, which contains updated equation of state and opacity tables as well as other improvements. Each series consists of a run without a cutoff in planetesimal accretion,

plus up to three runs with a cutoff at a particular core mass. The first series of runs is computed with an atmospheric opacity due to grains (hereafter referred to as ‘grain opacity’) that is 2% of the interstellar value and $\sigma_{init,Z} = 10$ g/cm². Cutoff runs are computed for core masses of 10, 5, and 3 M_{\oplus} . The second series of Jupiter models is computed with the grain opacity at the full interstellar value and $\sigma_{init,Z} = 10$ g/cm². Cutoff runs are computed for core masses of 10 and 5 M_{\oplus} . The third series of runs is computed with the grain opacity at 2% of the interstellar value and $\sigma_{init,Z} = 6$ g/cm². One cutoff run is computed with a core mass of 5 M_{\oplus} . The final series consists of one run, without a cutoff, which is computed with a temperature dependent grain opacity (i.e., 2% of the interstellar value for $T < 350$ K ramping up to the full interstellar value for $T > 500$ K) and $\sigma_{init,Z} = 10$ g/cm².

Our results demonstrate that reducing grain opacities results in formation times less than half of those for models computed with full interstellar grain opacity values. The reduction of opacity due to grains in the upper portion of the envelope with $T \leq 500$ K has the largest effect on the lowering of the formation time. If the accretion of planetesimals is not cut off prior to the accretion of gas, then decreasing the surface density of planetesimals lowers the final core mass of the protoplanet, but increases the formation timescale considerably. Finally, a core mass cutoff results in a reduction of the time needed for a protoplanet to evolve to the stage of runaway gas accretion, provided the cutoff mass is sufficiently large. The overall results indicate that, with reasonable parameters, it is possible that Jupiter formed at 5 AU via the core accretion process in 1 Myr with a core of 10 M_{\oplus} or in 5 Myr with a core of 5 M_{\oplus} .

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Accurate magnetic field measurements of Vega-like stars and Herbig Ae/Be stars

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We obtained accurate circular spectropolarimetric observations of a sample of Vega-like and Herbig Ae/Be stars with FORS1 at the VLT in an attempt to detect their magnetic fields. No magnetic field could be diagnosed in any Vega-like star. The most accurate determination of a magnetic field, at 2.6σ level, was performed for the Vega-like star ι Cen, for which we measured $\langle B_z \rangle = -77 \pm 30$ G. In the prototype of Vega-like stars, the star β Pictoris, which shows conspicuous signs of chromospheric activity, a longitudinal magnetic field is measured only at $\sim 1.5\sigma$ level. We diagnosed a longitudinal magnetic field for the first time at a level higher than 3σ for the two Herbig Ae stars HD 31648 and HD 144432 and confirm the existence of a previously detected magnetic field in a third Herbig Ae star, HD 139614. Finally, we discuss the discovery of distinctive Zeeman features in the unusual Herbig Ae star HD 190073, where the Ca II doublet displays several components in both H and K lines. From the measurement of circular polarization in all Balmer lines from H_{β} to H_8 , we obtain $\langle B_z \rangle = +26 \pm 34$ G. However, using only the Ca II H and K lines for the measurement of circular polarization, we are able to diagnose a longitudinal magnetic field at 2.8σ level, $\langle B_z \rangle = +84 \pm 30$ G.

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Isotopic abundances of carbon and nitrogen in Jupiter-family and Oort Cloud comets

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The $^{12}\text{C}^{14}\text{N}/^{12}\text{C}^{15}\text{N}$ and $^{12}\text{C}^{14}\text{N}/^{13}\text{C}^{14}\text{N}$ isotopic ratios are determined for the first time in a Jupiter-family comet, 88P/1981 Q1 Howell, and in the chemically peculiar Oort Cloud comet C/1999 S4 (LINEAR). By comparing these measurements to previous ones derived for six other Oort Cloud comets (including one of Halley-type), we find that both the carbon and nitrogen isotopic ratios are constant within the uncertainties. The mean values are $^{12}\text{C}/^{13}\text{C} \simeq 90$ and $^{14}\text{N}/^{15}\text{N} \simeq 145$ for the eight comets. These results strengthen the view that CN radicals originate from refractory organics formed in the protosolar molecular cloud and subsequently incorporated in comets.

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On the Ionisation Fraction in Protoplanetary Disks I: Comparing Different Reaction Networks

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We calculate the ionisation fraction in protostellar disk models using a number of different chemical reaction networks, including gas-phase and gas-grain reaction schemes. The disk models we consider are conventional alpha-disks, which include viscous heating and radiative cooling. The primary source of ionisation is assumed to be X-ray irradiation from the central star. We consider a number of gas-phase chemical networks. In general we find that the simple models predict higher fractional ionisation levels and more extensive active zones than the more complex models. When heavy metal atoms are included the simple models predict that the disk is magnetically active throughout. The complex models predict that extensive regions of the disk remain magnetically uncoupled even with a fractional abundance of magnesium of $10(-8)$. The addition of submicron sized grains with a concentration of $10(-12)$ causes the size of the dead zone to increase dramatically for all kinetic models considered. We find that the simple and complex gas-grain reaction schemes agree on the size and structure of the resulting dead zone. We examine the effects of depleting the concentration of small grains as a crude means of modeling the growth of grains during planet formation. We find that a depletion factor of $10(-4)$ causes the gas-grain chemistry to converge to the gas-phase chemistry when heavy metals are absent. $10(-8)$ is required when magnesium is included. This suggests that efficient grain growth and settling will be required in protoplanetary disks, before a substantial fraction of the disk mass in the planet forming zone between 1 - 10 AU becomes magnetically active and turbulent.

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<http://www.maths.qmul.ac.uk/~rpn/preprints/>

On the Ionisation Fraction in Protoplanetary Disks II: The Effect of Turbulent Mixing on Gas-phase Chemistry

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We calculate the ionisation fraction in protostellar disk models using two different gas-phase chemical networks, and examine the effect of turbulent mixing by modelling the diffusion of chemical species vertically through the disk. The aim is to determine in which regions of the disk gas can couple to a magnetic field and sustain MHD turbulence. We find that the effect of diffusion depends crucially on the elemental abundance of heavy metals (magnesium) included in the chemical model. In the absence of heavy metals, diffusion has essentially no effect on the ionisation structure of the disks, as the recombination time scale is much shorter than the turbulent diffusion time scale. When metals are included with an elemental abundance above a threshold value, the diffusion can dramatically reduce the size of the magnetically decoupled region, or even remove it altogether. For a complex chemistry the elemental abundance of magnesium required to remove the dead zone is $10(-10)$ - $10(-8)$. We also find that diffusion can modify the reaction pathways, giving rise to dominant species when diffusion is switched on that are minor species when diffusion is absent. This suggests that there may be chemical signatures of diffusive mixing that could be used to indirectly detect turbulent activity in protoplanetary disks. We find examples of models in which the dead zone in the outer disk

region is rendered deeper when diffusion is switched on. Overall these results suggest that global MHD turbulence in protoplanetary disks may be self-sustaining under favourable circumstances, as turbulent mixing can help maintain the ionisation fraction above that necessary to ensure good coupling between the gas and magnetic field.

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A circumstellar disk associated with a massive protostellar object

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The formation process for stars with masses several times that of the Sun is still unclear. The two main theories are mergers of several low-mass young stellar objects, which requires a high stellar density, or mass accretion from circumstellar disks in the same way as low-mass stars are formed, accompanied by outflows during the process of gravitational infall. Although a number of disks have been discovered around low- and intermediate-mass young stellar objects, the presence of disks around massive young stellar objects is still uncertain and the mass of the disk system detected around one such object, M17, is disputed. Here we report near-infrared imaging polarimetry that reveals an outflow/disk system around the Becklin-Neugebauer protostellar object, which has a mass of at least seven solar masses (M_{\odot}). This strongly supports the theory that stars with masses of at least $7M_{\odot}$ form in the same way as lower mass stars.

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Dark Cloud Cores and Gravitational Decoupling from Turbulent Flows

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We test the hypothesis that the starless cores may be gravitationally bound clouds supported largely by thermal pressure by comparing observed molecular line spectra to theoretical spectra produced by a simulation that includes hydrodynamics, radiative cooling, variable molecular abundance, and radiative transfer in a simple one-dimensional model. The results suggest that the starless cores can be divided into two categories: stable starless cores that are in approximate equilibrium and will not evolve to form protostars, and unstable pre-stellar cores that are proceeding toward gravitational collapse and the formation of protostars. The starless cores might be formed from the interstellar medium as objects at the lower end of the inertial cascade of interstellar turbulence. Additionally, we identify a thermal instability in the starless cores. Under particular conditions of density and mass, a core may be unstable to expansion if the density is just above the critical density for the collisional coupling of the gas and dust so that as the core expands the gas-dust coupling that cools the gas is reduced and the gas warms, further driving the expansion.

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Observations on the Formation of Massive Stars by Accretion

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Observations of the H66 α recombination line from the ionized gas in the cluster of newly formed massive stars, G10.6–0.4, show that most of the continuum emission derives from the dense gas in an ionized accretion flow that forms an ionized disk or torus around a group of stars in the center of the cluster. The inward motion observed in the accretion flow suggests that despite the equivalent luminosity and ionizing radiation of several O stars, neither radiation pressure nor thermal pressure has reversed the accretion flow. The observations indicate why the radiation pressure of the stars and the thermal pressure of the HII region are not effective in reversing the accretion flow. The observed rate of the accretion flow, $10^{-3} M_{\odot} \text{ yr}^{-1}$, is sufficient to form massive stars within the time scale imposed by their short main sequence lifetimes. A simple model of disk accretion relates quenched HII regions, trapped hypercompact HII regions, and photo-evaporating disks in an evolutionary sequence

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M82, Starbursts, Star Clusters, and the formation of Globular Clusters

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We observed the nearby starburst galaxy M82 in CO in the higher frequency (2–1) transition to achieve an angular resolution below 1 arc second or 17 pc at the target. We resolved the molecular gas into a large number of compact clouds, with masses ranging from $\sim 2 \times 10^3$ to $2 \times 10^6 M_{\odot}$. The mass spectrum scales as $N(M) \propto M^{-1.5 \pm 0.1}$, similar to the mass spectra of young massive star clusters suggesting that individual molecular clouds are transformed in the starburst into individual star clusters. The larger clouds are surrounded by supernovae and HII regions suggesting that star formation proceeds from the outside of the clouds and progresses inward consistent with triggering by a sudden increase in external pressure. The clouds with internal star formation have velocity gradients and inverse P-Cygni spectral line profiles indicating inward motions of 35 kms^{-1} consistent with shock driven compression. Diffuse free-free radio emission and X-ray emission around the clouds provides evidence for superheated ionized gas sufficient to drive the compression. Clouds with spectral lines indicating expansion show little internal star formation suggesting that the dynamics precedes and is responsible for the star formation rather than the inverse. M82 is known to be in interaction with neighboring M81. The overall picture is consistent with the formation of massive star clusters from individual giant molecular clouds crushed by a sudden galactic scale increase in external pressure generated by the changing dynamics that result from a near-collision with a neighboring galaxy. Present day globular clusters may have formed in a similar fashion in primordial galaxies.

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CO in H I Self-absorbed Clouds in Perseus

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We have observed $^{12}\text{CO } J = 2 \rightarrow 1$ and $J = 1 \rightarrow 0$ and $^{13}\text{CO } J = 1 \rightarrow 0$ emission in two regions of H I self-

absorption (HISA) in Perseus: a small, isolated HISA feature called the "globule" and a more extended HISA cloud called the "complex." Using both large velocity gradient and Monte Carlo radiative transfer codes, we found that in the globule $N(^{12}\text{CO}) < 6.0 \times 10^{15} \text{cm}^{-2}$, which, using photodissociation region (PDR) models, implies that $N(\text{H}_2) < 9.9 \times 10^{20} \text{cm}^{-2}$. In the complex we found that the H_2 column densities were in the range $(1.2\text{-}2.2) \times 10^{21} \text{cm}^{-2}$. By comparing the HISA and CO observations we were able to constrain the physical conditions and atomic gas fraction (f). In the globule, $8 \text{ K} \leq T_{\text{spin}} \leq 22 \text{ K}$ and $0.02 \leq f \leq 0.2$, depending on whether the (unknown) gas density was 10^2 , 10^3 , or 10^4 cm^{-3} . In the complex, $12 \text{ K} \leq T_{\text{spin}} \leq 24 \text{ K}$ and $0.02 \leq f \leq 0.05$, and we were also able to constrain the gas density ($100 \text{cm}^{-3} < n < 1200 \text{cm}^{-3}$). These results imply that the gas in the HISA clouds is colder and denser than that usually associated with the atomic ISM and, indeed, is similar to that seen in molecular clouds. The small atomic gas fractions also imply that there is a significant molecular component in these HISA clouds, even when little or no ^{12}CO is detected. The level of ^{12}CO detected and the visual extinction due to dust is consistent with the idea that these HISA clouds are undergoing a transition from the atomic to molecular phase.

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The evidence of an early stellar encounter in Edgeworth-Kuiper belt

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We investigate the influence of a stellar fly-by encounter on the Edgeworth-Kuiper belt objects through numerical orbital calculations, in order to explain both mass depletion and high orbital inclinations of the classical Edgeworth-Kuiper belt (CEKB) objects, which have semimajor axis of 42-48 AU and perihelia beyond 35 AU. The observationally inferred total mass of the CEKB is $\sim 1/10$ Earth masses, which is only ~ 0.02 of that extrapolated from the minimum-mass solar nebula model. The CEKB consists of bimodal population: "hot population" with inclinations $i \simeq 0.2 - 0.6$ radians and "cold population" with $i \simeq 0.1$. The observationally suggested difference in size and color of objects between the two populations may imply different origins of the two populations. We find that both the depletion of solid materials in the CEKB and the formation of the hot population are accounted for by a single close stellar encounter with pericenter distance of 80-100 AU and inclination relative to the initial protoplanetary disk $\simeq 50^\circ - 70^\circ$. Such a stellar encounter highly pumps up eccentricities of most objects in the CEKB and then their perihelia migrate within 35 AU. These objects would be removed by Neptune's perturbations after Neptune is formed at or migrates to the current position (30 AU). Less than 10% of the original objects remain in stable orbits with small eccentricities and perihelion distances larger than 35 AU, in the CEKB, which is consistent with the observation. We find that i of the remaining objects are as large as that of the observed hot population. The only problem is how to stop Neptune's migration at ~ 30 AU, which is addressed in a separate paper. The depletion by the stellar encounter extends deeply into $\sim 30\text{-}35$ AU, which provides the basis of the formation model for the cold population through Neptune's outward migration by Levison and Morbidelli (2003, Nature, 426, 419-421). The combination of our model with Levison and Morbidelli's model could consistently explain the mass depletion, truncation at 50 AU, bimodal distribution in i , and differences in size and color between the hot and the cold populations in the CEKB.

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Photophoresis and the Pile-up of Dust in Young Circumstellar Disks

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A rapidly growing number of observations reveal ever more structure in young circumstellar disks that are presumed to be forming planetary systems. Prominent features observed are ring-shaped dust distributions with sharp inner edges around stars like the young, main-sequence star HR 4796A. Models aiming to explain the formation of these dust rings by grain migration incorporate radiation pressure of the central star as one shaping force in radial direction. However, the radiometric effect of photophoresis has been ignored, so far, in this context. This effect is based on a

radiation-induced temperature gradient on the surface of a particle and the consequential nonuniform interaction with surrounding gas. The resulting force is able to effectively influence the motion of particles in gaseous environments, but so far photophoresis has been limited to applications in the field of aerosol science. Here we present calculations that underline the relevance of the photophoretic force for the dynamics of particles in gas-rich, optically thin circumstellar disks. Depending on the gas pressure, photophoresis can be stronger than radiation pressure, gas drag, and gravity by orders of magnitude. Then the motion of particles ranging in size from 1 μm to 10 μm will be dominated by photophoresis. Since the photophoretic force is a function of the gas density, it provides an efficient mechanism for fast radial migration of particles to a definite distance from the star where the gas density reaches a value at which photophoresis is in equilibrium with all other forces at work. By this effect, material is swept out from the inner region of the disk and piled-up in a more or less confined belt around the star. Thus, the formation of ringlike structures of the dust distribution can most naturally be explained without any further assumptions. Since photophoretic pile-up also works for larger bodies, it might even trigger the formation of Kuiper belts.

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Near-Infrared Photometric Monitoring of a Pre-Main Sequence Object KH 15D

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An extensive photometric monitoring of KH 15D, an enigmatic variable in the young star cluster NGC 2264, has been conducted. Simultaneous and accurate near-infrared (*JHKs*-bands) photometry is presented between 2003 December and 2005 March covering most of the variable phase. The infrared variability is characterized by large-amplitude and long-lasting eclipse, as observed at optical. The period of variability is 48.3 ± 0.2 days, the maximum photometric amplitude of variability is ~ 4.2 mag, and the eclipse duration is ~ 0.5 in phase units. These are consistent with the most recent period, amplitude, and duration at optical. The blueing of the *J-H* color (~ 0.16 mag) during the eclipse, which has been suggested before, is unambiguously confirmed; a similar blueing at *H-Ks* is less clear but is probably present at a similar level. The overall shape of the *JHKs* light curves is very similar to the optical one, including a fair time-symmetry and a less stable flux during the eclipse with a slight hump near the zero phase. Most of these variability features of KH 15D observed at near-infrared wavelengths can be explained with the recent model employing an eclipse by the inclined, precessing disk and an outer scattering region around a pre-main-sequence binary.

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Two 2MASS-Selected Young Stellar Clusters: Photometry, Spectroscopy, and the Initial Mass Function

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We present near-IR (NIR) *J*, *H*, and *K_s* images and *K*-band spectroscopy of two newly discovered stellar clusters at

different stages of evolution. Our spectra suggest the presence of massive young stellar objects in the heavily embedded cluster in the star-forming region near radio source G353.4-0.4 and an O5-O6 V star in the cluster near radio source G305+00.2. We determine a K -band luminosity function (KLF) for both clusters and an initial mass function (IMF) for the cluster near G305+00.2. The derived IMF slope is $\Gamma = -1.5$ if the KLF is used to derive the IMF and is $\Gamma = -0.98$ if the color-magnitude diagram (CMD) and spectra are used. The more reliable CMD-based slope is flatter than the Salpeter value usually found for stellar clusters. We find that using the KLF alone to derive an IMF is likely to produce an overly steep slope in stellar clusters subject to variable extinction.

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Outflows from young objects observed with the ISO-LWS: I. Fine structure lines [O I] 63 μm , [O I] 145 μm and [C II] 157 μm

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Far infrared fine structure line data from the ISO archive have been extracted for several hundred YSOs and their outflows, including molecular (CO) outflows, optical jets and Herbig-Haro (HH) objects. Given the importance of these lines to astrophysics, their excitation and transfer ought to be investigated in detail and, at this stage, the reliability of the diagnostic power of the fine structure transitions of O I and C II has been examined. Several issues, such as the extremely small intensity ratios of the oxygen 63 μm to 145 μm lines, are still awaiting an explanation. It is demonstrated that, in interstellar cloud conditions, the 145 μm line is prone to masing, but that this effect is likely an insufficient cause of the line ratio anomaly observed from cold dark clouds. Very optically thick emission could in principle also account for this, but would need similar, prohibitively high column densities and must therefore be abandoned as a viable explanation. One is left with [O I] 63 μm self absorption by cold and tenuous foreground gas, as has been advocated for distant luminous sources. Recent observations with the submillimeter observatory Odin support this scenario also in the case of nearby dark molecular clouds. On the basis of this large statistical material we are led to conclude that in star forming regions, the [O I] and [C II] lines generally have only limited diagnostic value.

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Constraints on the formation mechanism of the planetary mass companion of 2MASS 1207334-393254

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In this paper we discuss the nature and the possible formation scenarios of the companion of the brown dwarf 2MASS 1207334-393254. We initially discuss the basic physical properties of this object and conclude that, although from its absolute mass ($5M_{\text{Jup}}$), it is a planetary object, in terms of its mass ratio q and of its separation a with respect to the primary brown dwarf, it is consistent with the statistical properties of binaries with higher primary mass. We then explore the possible formation mechanism for this object. We show that the standard planet formation mechanism of core accretion is far too slow to form this object within 10 Myr, the observed age of the system. On the other hand, the alternative mechanism of gravitational instability (proposed both in the context of planet and of binary formation) may, in principle, work and form a system with the observed properties.

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Exploring Terrestrial Planet Formation in the TW Hydrae Association

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Spitzer Space Telescope infrared measurements are presented for 24 members of the TW Hya association (TWA). High signal-to-noise ratio 24 μm photometry is presented for all these stars, including 20 stars that were not detected by IRAS. Among these 20 stars, only a single object, TWA 7, shows excess emission at 24 μm at the level of only 40% above the star's photosphere. TWA 7 also exhibits a strong 70 μm excess that is a factor of 40 brighter than the stellar photosphere at this wavelength. At 70 μm , an excess of similar magnitude is detected for TWA 13, although no 24 μm excess was detected for this binary. For the 18 stars that failed to show measurable IR excesses, the sensitivity of the current 70 μm observations does not rule out substantial cool excesses at levels 10-40 times above their stellar continua. Measurements of two T Tauri stars, TW Hya and Hen 6-300, confirm that their spectacular IR spectral energy distributions (SEDs) do not turn over even by 160 μm , consistent with the expectation for their active accretion disks. In contrast, the *Spitzer* data for the luminous planetary debris systems in the TWA, HD 98800B and HR 4796A, are consistent with single-temperature blackbody SEDs and agree with previous IR, submillimeter, and millimeter measurements. The major new result of this study is the dramatic bimodal distribution found for the association in the form of excess emission at a wavelength of 24 μm , indicating negligible amounts of warm (≥ 100 K) dust and debris around 20 of 24 stars in this group of very young stars. This bimodal distribution is especially striking given that the four stars in the association with strong IR excesses are ≥ 100 times brighter at 24 μm than their photospheres. Clearly, two terrestrial planetary systems, HD 98800B and HR 4796A, exist in some form. In addition, there are at least two active accreting objects, TW Hya and Hen 6-300, that may still be forming planetesimals. The remaining stars may possess significant amounts of cold dust, as in TWA 7 and 13, that have yet to be found.

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The Disk Fractions of Brown Dwarfs in IC 348 and Chamaeleon I

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Using the Infrared Array Camera (IRAC) aboard the *Spitzer Space Telescope*, we have obtained mid-infrared photometry for 25 and 18 low-mass members of the IC 348 and Chamaeleon I star-forming clusters, respectively ($>M6$, $M \leq 0.08M_{\odot}$). We find that $42\% \pm 13\%$ and $50\% \pm 17\%$ of the two samples exhibit excess emission indicative of circumstellar disks. In comparison, the disk fractions for stellar members of these clusters are $33\% \pm 4\%$ and $45\% \pm 7\%$ ($M0-M6$, $0.7M_{\odot} \geq M \geq 0.1M_{\odot}$). The similarity in the disk fractions of stars and brown dwarfs is consistent with a common formation mechanism and indicates that the raw materials for planet formation are available around brown dwarfs as often as around stars.

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Expansion of the TW Hydrae association and the encounter with Vega

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We investigate the paths of several probable members of the young association around the star TW Hydrae (TWA) with accurate distances, proper motions and radial velocities. We find that three of the previously identified members, TWA 1, TWA 4 and TWA 11, together with two other young nearby stars, HD 139084 and HD 220476, form a rapidly expanding association with an expansion age of 4.7 ± 0.6 Myr. Initial velocities of member stars with respect to the common centre of mass range from 4 to 10 km s⁻¹. A characteristic size of the association in the initial configuration is 21 pc, which may be somewhat biased upwards due to the uncertainties in the observational data. The Lower Centaurus Crux (LCC) OB association passed near TWA, at a distance of 36 ± 6 pc, 11 Myr ago. A plausible scenario, which accounts for the difference between the isochrone age (≈ 10 Myr) and expansion age (5 Myr), is that star formation was stimulated in the TWA progenitor cloud by the near passage of the LCC, but that the newly formed stars were not released from the cloud until a subsequent collision with one of the other molecular clouds in the North Ophiuchus region. Vega was inside the TWA association, and close to its centre of gravity, at the time of maximum compression 4.7 Myr ago. If this alignment is a chance encounter, the powerful particular disc around Vega could have been enhanced by the passage through the TWA progenitor cloud at 8 km s⁻¹.

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Disk and wind interaction in the young stellar object MWC 297 spatially resolved with VLTI/AMBER

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The young stellar object MWC 297 is an embedded B1.5Ve star exhibiting strong hydrogen emission lines and a strong near-infrared continuum excess. This object has been observed with the VLT interferometer equipped with the AMBER instrument during its first commissioning run. VLTI/AMBER is currently the only near infrared interferometer which can observe spectrally dispersed visibilities. MWC 297 has been spatially resolved in the continuum with a visibility of $0.50_{-0.10}^{+0.08}$ as well as in the Br γ emission line where the visibility decrease to a lower value of 0.33 ± 0.06 . This change in the visibility with the wavelength can be interpreted by the presence of an optically thick disk responsible for the visibility in the continuum and of a stellar wind traced by the Br γ emission line and whose apparent size is 40% larger. We validate this interpretation by building a model of the stellar environment that combines a geometrically thin, optically thick accretion disk model consisting of gas and dust, and a latitude-dependent stellar wind outflowing above the disk surface. The continuum emission and visibilities obtained from this model are fully consistent with the interferometric AMBER data. They agree also with existing optical, near-infrared spectra and other broad-band near-infrared interferometric visibilities. We also reproduce the shape of the visibilities in the Br γ line as well as the profile of this line obtained at a higher spectral resolution with the VLT/ISAAC spectrograph, and those of the H α and H β lines. The disk and wind models yield a consistent inclination of the system of approximately 20°. A picture emerges in which MWC 297 is surrounded by an equatorial flat disk that is possibly still accreting and an outflowing wind which has a much higher velocity in the polar region than at the equator. The VLTI/AMBER unique capability to measure spectral visibilities therefore allows us for the first time to compare the apparent geometry of a wind with the disk structure in a young stellar system.

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Accretion-powered Stellar Winds as a Solution to the Stellar Angular Momentum Problem

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We compare the angular momentum extracted by a wind from a pre-main-sequence star to the torques arising from the interaction between the star and its Keplerian accretion disk. We find that the wind alone can counteract the spin-up torque from mass accretion, solving the mystery of why accreting pre-main-sequence stars are observed to spin at less than 10% of break-up speed, provided that the mass outflow rate in the stellar winds is $\sim 10\%$ of the accretion rate. We suggest that such massive winds will be driven by some fraction ϵ of the accretion power. For observationally constrained typical parameters of classical T-Tauri stars, ϵ needs to be between a few and a few tens of percent. In this scenario, efficient braking of the star will terminate simultaneously with accretion, as is usually assumed to explain the rotation velocities of stars in young clusters.

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Confirmation of a Stellar microjet in the Rosette H II region (NGC 2244)

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A possible microjet from a low-mass but young star, which has already shed its cocoon, could be rendered observable

by the Lyman photon flux in the interior of the Rosette Nebula. Outside this environment it may not have been observable at optical wavelengths. The kinematics of this proposed monopolar microjet from an F8 Ve star have been investigated by spatially resolved, long-slit, spectral observations with the Manchester Echelle Spectrometer on the San Pedro Martir telescope (Mexico). The flow is shown to be approaching to give a radial velocity difference from the host nebula of -56 km s^{-1} . An outflow velocity of, at the most, a few hundreds of km s^{-1} is therefore indicated. If the flow velocity is taken as 200 km s^{-1} , which is found in other microjets, then this jet's inclination to the sky is 16° . The mass in the outflowing ionized gas is estimated from the surface brightness of the $\text{H}\alpha$ emission as $\approx 6 \times 10^{27} \text{ g}$ to give an estimated mass-loss rate of $10^{-8} M_\odot \text{ yr}^{-1}$, which, along with the detection of the outflow velocity, confirms its microjet identification even though an uncertain filling factor was used in these calculations. The hottest cluster star, which is also in the neighborhood of the microjet, is found alone to emit marginally sufficient Lyman photons to account for the ionization of the jet, although direct observations of the local electron density from optical line ratios are required to confirm this point conclusively.

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Young stars and dust in AFGL437: NICMOS/HST polarimetric imaging of an outflow source

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We present near infrared broad band and polarimetric images of the compact star forming cluster AFGL437 obtained with the NICMOS instrument aboard HST. Our high resolution images reveal a well collimated bipolar reflection nebulosity in the cluster and allow us to identify WK34 as the illuminating source. The scattered light in the bipolar nebulosity centered on this source is very highly polarized (up to 79%). Such high levels of polarization implies a distribution of dust grains lacking large grains, contrary to the usual dust models of dark clouds. We discuss the geometry of the dust distribution giving rise to the bipolar reflection nebulosity and make mass estimates for the underlying scattering material. We find that the most likely inclination of the bipolar nebulosity, south lobe inclined towards Earth, is consistent with the inclination of the large scale CO molecular outflow associated with the cluster, strengthening the identification of WK34 as the source powering it.

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Evolution of the ISM of starburst galaxies: The SN heating efficiency

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The interstellar medium heated by supernova explosions (SN) may acquire an expansion velocity larger than the escape velocity and leave the galaxy through a supersonic wind. Galactic winds are effectively observed in many local starburst galaxies. SN ejecta are transported out of the galaxies by such winds which thus affect the chemical evolution of the galaxies. The effectiveness of the processes mentioned above depends on the heating efficiency (HE) of the SNe, i.e. on the fraction of SN energy which is not radiated away. The value of HE, in particular in starburst (SB) galaxies, is a matter of debate. We have constructed a simple semi-analytic model, considering the essential ingredients of a SB environment which is able to qualitatively trace the thermalisation history of the ISM in a SB region and determine the HE evolution. Our study has been also accompanied by fully 3-D radiative cooling, hydrodynamical simulations of SNR-SNR and SNR-clouds interactions. We find that, as long as the typical time scale of mass-loss of the clouds to the ambient medium, which is often dominated by photoevaporation, remains shorter than the time scale at which the SNRs interact to form a superbubble, the SN heating efficiency remains very small, as radiative cooling of the gas dominates. If there is a continuous production of clouds by the gas swept by the SNR shells, this occurs during the first $\sim 16 \text{ Myr}$ of the SB activity (of $\sim 30 \text{ Myr}$), after which the efficiency rapidly increases to one, leading to a possible galactic wind formation. Under an extreme condition in which no clouds are allowed to form, other than

those that were already initially present in the SB environment, then in this case HE increases to one in only few Myr. We conclude that the HE value has a time-dependent trend that is sensitive to the initial conditions of the system and cannot be simply assumed to be ~ 1 , as it is commonly done in most SB galactic wind models.

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Multidimensional hydrodynamical simulations of radiative cooling SNRs-clouds interactions: an application to starburst environments

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Most galaxies present supernova shock fronts interacting with cloudy interstellar medium. These interactions can occur either at small scales, between a single supernova remnant (SNR) and a compact cloud, or at large scales, between a giant shell of a superbubble and a molecular cloud. Here study the by-products of SNR-clouds in a starburst (SB) system. Due to the high supernova (SN) rate in this environment, a cloud may be shocked more than once by SNRs. These interactions can have an important role in the recycling of matter from the clouds to the ISM and vice-versa. Their study is also relevant to understand the evolution of the ISM density and the structure of the clouds embedded in it. In the present work, we have focused our attention on the global effects of the interactions between clouds and SN shock waves in the ISM of SB environments and performed three-dimensional radiative cooling hydrodynamical simulations which have included the continuity equations for several atomic/ionic and molecular species. We have also considered the effects of the photo-evaporation due to the presence of the UV radiation from hot stars and SNe. The results have shown that due to the presence of radiative cooling, the interactions cause the formation of elongated cold filaments, instead of favoring an efficient mixing of the cloud gas with the diffuse ISM. These filaments could be associated with the dense clumps observed inside several SBs that are blown out by the galactic wind. The results have also revealed that the SNR-cloud interactions are less efficient at producing substantial mass loss from the clouds to the diffuse ISM than mechanisms such as the photo-evaporation caused by the UV flux from the hot stars. This result has important consequences for the global evolution of the SB environment and the formation of the associated superwinds, and may also be relevant to the ISM of normal galaxies.

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First results from a VLBA proper motion survey of H₂O masers in low-mass YSOs: the Serpens core and RNO 15-FIR.

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This article reports first results of a long-term observational program aimed to study the earliest evolution of jet/disk systems in low-mass YSOs by means of VLBI observations of the 22.2 GHz water masers. We report here data for the cluster of low-mass YSOs in the Serpens molecular core and for the single object RNO 15-FIR. Towards Serpens SMM1, the most luminous sub-mm source of the Serpens cluster, the water maser emission comes from two small (≤ 5 AU in size) clusters of features separated by ≈ 25 AU, having line of sight velocities strongly red-shifted (by more than 10 km s^{-1}) with respect to the LSR velocity of the molecular cloud. The two maser clusters are oriented

on the sky along a direction that is approximately perpendicular to the axis of the radio continuum jet observed with the VLA towards SMM1. The spatial and velocity distribution of the maser features lead us to favor the interpretation that the maser emission is excited by interaction of the receding lobe of the jet with dense gas in the accretion disk surrounding the YSO in SMM1. The line of sight velocities of several features decrease at a rate of $\approx 1 \text{ km s}^{-1} \text{ month}^{-1}$ and the sky-projected relative motion of two features appears to be accelerated (decelerated) at a rate of $\approx 10\text{--}15 \text{ km s}^{-1} \text{ month}^{-1}$. We propose that the shocks harboring the maser emission are slowed down as they proceed through the dense material surrounding the YSO. Towards RNO 15-FIR, the few detected maser features have both positions and (absolute) velocities aligned along a direction that is parallel to the axis of the molecular outflow observed on much larger angular scales. In this case the maser emission likely emerges from dense, shocked molecular clumps displaced along the axis of the jet emerging from the YSO. The protostar in Serpens SMM1 is more massive than the one in RNO 15-FIR. We discuss the case where a high mass ejection rate can generate jets sufficiently powerful to sweep away from their course the densest portions of circumstellar gas. In this case, the excitation conditions for water masers might preferably occur at the interface between the jet and the accretion disk, rather than along the jet axis.

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On the Orbital Evolution of Low Mass Protoplanets in Turbulent, Magnetised Disks

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We present the results of MHD simulations of low mass protoplanets interacting with turbulent, magnetised protostellar disks. We calculate the orbital evolution of ‘planetesimals’ and protoplanets with masses in the range $0 \leq m_p \leq 30 M_{\oplus}$. The disk models are cylindrical models with toroidal net-flux magnetic fields, having aspect ratio $H/r = 0.07$ and effective viscous stress parameter $\alpha \simeq 5 \times 10^{-3}$.

A significant result is that the $m_p = 0$ ‘planetesimals’, and protoplanets of all masses considered, undergo stochastic migration due to gravitational interaction with turbulent density fluctuations in the disk. For simulation run times currently feasible (covering between 100 – 150 planet orbits), the stochastic migration dominates over type I migration for many models. Fourier analysis of the torques experienced by protoplanets indicates that the torque fluctuations contain components with significant power whose time scales of variation are similar to the simulation run times. These long term torque fluctuations in part explain the dominance of stochastic torques in the models, and may provide a powerful means of counteracting the effects of type I migration acting on some planets in turbulent disks. The effect of superposing type I migration torques appropriate for laminar disks on the stochastic torques was examined. This analysis predicts that a greater degree of inward migration should occur than was observed in the MHD simulations. This may be a first hint that type I torques are modified in a turbulent disk, but the results are not conclusive on this matter.

The turbulence is found to be a significant source of eccentricity driving, with the ‘planetesimals’ attaining eccentricities in the range $0.02 \leq e \leq 0.14$ during the simulations. The eccentricity evolution of the protoplanets shows strong dependence on the protoplanet mass. Protoplanets with mass $m_p = 1 M_{\oplus}$ attained eccentricities in the range $0.02 \leq e \leq 0.08$. Those with $m_p = 10 M_{\oplus}$ reached $0.02 \leq e \leq 0.03$. This trend is in basic agreement with a model in which eccentricity growth arises because of turbulent forcing, and eccentricity damping occurs through interaction with disk material at coorbital Lindblad resonances.

These results are significant for the theory of planet formation. Stochastic migration may provide a means of preventing at least some planetary cores from migrating into the central star due to type I migration before they become gas giants. The growth of planetary cores may be enhanced by preventing isolation during planetesimal accretion. The excitation of eccentricity by the turbulence, however, may act to reduce the growth rates of planetary cores during the runaway and oligarchic growth stages, and may cause collisions between planetesimals to be destructive rather than accumulative.

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Are Presolar Silicon Carbide Grains from Novae Actually from Supernovae?

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We report Si, C, N, Mg-Al, Ca, and Ti isotopic data for three micron-sized presolar SiC grains from the Murchison meteorite. These grains have very low $^{12}\text{C}/^{13}\text{C}$ and $^{14}\text{N}/^{15}\text{N}$ ratios, similar to grains for which an origin in classical ONe novae has been previously ascribed. Isotopic signatures in one grain (^{28}Si , ^{49}Ti , and ^{44}Ca excesses and a very high inferred $^{26}\text{Al}/^{27}\text{Al}$ ratio) indicate that it in fact formed in a supernova, not a nova. Similarly, a large ^{47}Ti excess in another grain argues against a nova origin. The new data raise the question whether all grains previously attributed to novae might have in fact originated in Type II supernovae. The results also point to coupled synthesis of ^{13}C and ^{15}N in Type II supernovae.

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HST Images Do Not Support the Presence of Three High Velocity, Low-Mass Runaway Stars in the Core of the Orion Nebula Cluster

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A recent article has employed the determination from groundbased images of high proper motions in the Orion Nebula Cluster to argue that JW 349, JW 355, and JW 451 are high velocity (38 km/s, 89 km/s, and 69 km/s, respectively) low mass runaway stars. We report on measurement of the proper motions of these stars using images made by the Hubble Space Telescope's WFPC2 imager and find that there is no evidence for motions above 6.2 km/s for JW 349 and 7.9 km/s for JW 355, while the motion of 5.5 km/s for JW 451 is only slightly larger than the measurement uncertainty of 3.9 km/s. We conclude that there is no observational support for these stars being high velocity runaway stars.

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On water ice formation in interstellar clouds

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A model is proposed for the formation of water ice mantles on grains in interstellar clouds. This occurs by direct accretion of monomers from the gas, be they formed by gas or surface reactions. The formation of the first monolayer requires a minimum extinction of interstellar radiation, sufficient to lower the grain temperature to the point where thermal evaporation of monomers is just offset by monomer accretion from the gas. This threshold is mainly determined by the adsorption energy of water molecules on the grain material; for hydrocarbon material, chemical simulation places this energy between 0.5 and 2 kcal mol⁻¹, which sets the (true) visible extinction threshold at a few magnitudes. However, realistic distributions of matter in a cloud will usually add to this an unrelated amount of cloud core extinction, which can explain the large dispersion of observed (apparent) thresholds. Once the threshold is crossed, all available water molecules in the gas are quickly adsorbed, because the grain cools down and the adsorption energy on ice is higher than on bare grain. The relative thickness of the mantle, and, hence, the slope of τ_3 (A_v) depend only on the available water vapour, which is a small fraction of the oxygen abundance. Chemical simulation was also used to determine the adsorption sites and energies of O and OH on hydrocarbons and study the dynamics of formation of water molecules by surface reactions with gaseous H atoms, as well as their chances to stick in situ.

Mid-infrared images of the massive star forming region W75 N

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An infrared study that includes ground-based mid-infrared images between 8.7 and 18.7 μm and IRAC images at 3.6, 4.5, 5.8 and 8.0 μm of the W75 N massive star forming region is presented. The 12.5 μm image shows the presence of four mid-infrared sources in the region W75 N(B), three of which have bright near-infrared counterparts, IRS 1, IRS 2 and IRS 3, all with significant excess emission at $\lambda > 2.0 \mu\text{m}$. IRS 2 has a steep energy distribution and the computed infrared luminosity is consistent with the presence of a young B3 star. The observed IRAC colors of IRS 3 indicate that this source is a Class II intermediate mass young star, consistent with its infrared energy distribution and luminosity. The fourth, newly discovered, mid-infrared source appears coincident with the ultracompact HII region VLA 3, and is located within the millimeter core MM 1. We derived a luminosity of $\sim 750 L_{\odot}$ and a visual extinction $A_V \simeq 90$ for this source. From the IRAC images, we detected 75 sources in an area of $120'' \times 120''$ centered in W75 N. At least 25 of these sources are associated with the molecular cloud and form a young stellar cluster as shown in the IRAC two-color and the $H - K_s$ versus $K_s - [3.6]$ diagrams.

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The excitation of water in the S140 photon dominated region.

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We consider the excitation of water in the Photon Dominated Region (PDR) S140. With the use of a three-dimensional escape probability method we compute the level populations of ortho- and para- H_2O up to ~ 350 K (i.e., 8 levels), as well as line intensities for various transitions. Homogeneous and inhomogeneous models are presented with densities of 10^4 – 10^5 cm^{-3} and the differences between the resulting intensities are displayed. Density, temperature, and abundance distributions inside the cloud are computed with the use of a self-consistent physico-chemical (in)homogeneous model in order to reproduce the line intensities observed with SWAS, and to make predictions for various lines that HIFI will probe in the future.

Line intensities vary from $\sim 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ to a few times $10^{-6} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$. We can reproduce the intensity for the $1_{10} \rightarrow 1_{01}$ line observed by the SWAS satellite. It is found that the $2_{12} \rightarrow 1_{01}$ line is the strongest, whereas the $3_{12} \rightarrow 2_{21}$ line is the weakest, in all the models. It is found that the $1_{10} \rightarrow 1_{01}$ line probes the total column, while higher excitation lines probe the higher density gas (e.g., clumps).

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Massive Protostars in the Infrared Dark Cloud MSXDC G034.43+00.24

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We present a multiwavelength study of the infrared dark cloud MSXDC G034.43+00.24. Dust emission, traced by millimeter/submillimeter images obtained with the IRAM, JCMT, and CSO telescopes, reveals three compact cores

within this infrared dark cloud with masses of 170-800 M_{\odot} and sizes >0.5 pc. Spitzer 3.6-8.0 μm images show slightly extended emission toward these cores, with a spectral enhancement at 4.5 μm that probably arises from shocked H_2 . In addition, the broad line widths ($\Delta V \sim 10 \text{ km s}^{-1}$) of HCN (4-3) and CS (3-2) and the detection of SiO (2-1), observed with the JCMT and IRAM telescopes, also indicate active star formation. Spitzer 24 μm images reveal that each of these cores contains a bright, unresolved continuum source; these sources are most likely embedded protostars. Their millimeter-to-mid-IR continuum spectral energy distributions reveal very high luminosities, 9000-32,000 L_{\odot} . Because such large luminosities cannot arise from low-mass protostars, MSXDC G034.43+00.24 is actively forming massive ($\sim 10M_{\odot}$) stars.

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Quantifying Orbital Migration from Exoplanet Statistics and Host Metallicities

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We investigate how the statistical distribution of extrasolar planets may be combined with knowledge of the host stars' metallicity to yield constraints on the migration histories of gas giant planets. At any radius, planets that barely manage to form around the lowest metallicity stars accrete their envelopes just as the gas disk is being dissipated, so the lower envelope of planets in a plot of metallicity versus semimajor axis defines a sample of nonmigratory planets that will have suffered less than average migration subsequent to gap opening. Under the assumption that metallicity largely controls the initial surface density of planetesimals, we use simplified core accretion models to calculate how the minimum metallicity needed for planet formation varies as a function of semimajor axis. Models that do not include core migration prior to gap opening (type I migration) predict that the critical metallicity is largely flat between the snow line and $a \approx 6$ AU, with a weak dependence on the initial surface density profile of planetesimals. When slow type I migration is included, the critical metallicity is found to increase steadily from 1 to 10 AU. Large planet samples that include planets at modestly greater orbital radii than present surveys therefore have the potential to quantify the extent of migration in both type I and type II regimes.

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Dust grain growth in disks around T Tauri stars

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We present 7-mm continuum observations of 14 low-mass pre-main-sequence stars in the Taurus-Auriga star-forming region obtained with the Very Large Array with $\sim 1.5''$ resolution and ~ 0.3 mJy rms sensitivity. For 10 objects, the circumstellar emission has been spatially resolved. The large outer disk radii derived suggest that the emission at this wavelength is mostly optically thin. The millimetre spectral energy distributions are characterised by spectral indices $\alpha = 2.3$ to 3.2. After accounting for contribution from free-free emission and corrections for optical depth, we determine dust opacity indices β in the range 0.5 to 1.6, which suggest that millimetre-sized dust aggregates are present in the circumstellar disks. Four of the sources with $\beta > 1$ may be consistent with submicron-sized dust as found in the interstellar medium. Our findings indicate that dust grain growth to millimetre-sized particles is completed within less than 1 Myr for the majority of circumstellar disks.

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The Molecular Accretion Flow in G10.6-0.4

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We have observed the ultracompact H II region G10.6-0.4 with the VLA in the 23 GHz continuum and the NH₃ (3, 3) inversion line. By analyzing the optical depth of the line as well as the kinematics, we have detected a flattened, rotating molecular accretion flow. We detect the fact that the highest column density gas is more flattened, that is, distributed more narrowly, than the lower column density gas, and that there is some inclination of the rotation axis. The rotation is sub-Keplerian, and the molecular gas is not in a rotationally supported disk. We do not find a single massive (proto-)star forming in a scaled-up version of low-mass star formation. Instead, our observations suggest a different mode of clustered massive star formation, in which the accretion flow flattens but does not form an accretion disk. Moreover, in this mode of star formation the central object can be a group of massive stars rather than a single massive star.

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An Infalling Torus of Molecular Gas around the Ultracompact H II Region G28.20-0.05

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We present new observations of the ultracompact H II region G28.20-0.05 in the 23 GHz continuum and the NH₃(1, 1), NH₃(2, 2), and NH₃(3, 3) lines. To explain the complicated kinematics of the molecular gas, we propose a model consisting of two components. One component is an infalling, equatorial torus of molecular gas, whose dense central region has been ionized to form the ultracompact H II region. The second component is a larger expanding molecular shell driven by some type of wide-angle outflow or wind. We estimate that the infall component includes more than 18 M_⊙ of molecular gas. We calculate the central mass to be 79 M_⊙, probably comprising more than one star. The arrangement of the molecular material suggests a connection to the other disklike structures seen around massive young stars. The central star in this case is more massive, and the whole region may be more evolved than other similar objects such as IRAS 20126+4104, IRAS 18089-1732, G192.16-3.84, and AFGL 5142.

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The Direct Detection of a (Proto)Binary/Disk System in IRAS 20126+4104

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We report the direct detection of a binary/disk system toward the high-mass (proto)stellar object IRAS 20126+4104 at infrared wavelengths. The presence of a multiple system had been indicated by the precession of the outflow and the double-jet system detected earlier at centimeter wavelengths. Our new *K*-, *L*-, and *M*-band infrared images, obtained with the UKIRT under exceptional seeing conditions on Mauna Kea, are able to resolve the central source for the first time, and we identify two objects separated by $\sim 0.5''$ (850 AU). The *K* and *L* images also uncover features characteristic of a nearly edge-on disk, similar to many low-mass protostars with disks: two emission regions oriented along an outflow axis and separated by a dark lane. The peaks of the *L*- and *M*-band and millimeter-wavelength emission are on the dark lane, presumably locating the primary young star. The thickness of the disk is measured to be ~ 850 AU for radii ≤ 1000 AU. Approximate limits on the NIR magnitudes of the two young stars indicate a high-mass system, although with much uncertainty. These results are a demonstration of the high-mass nature of the system, and of the similarities of the star formation process in the low-mass and high-mass regimes, viz., the presence of a disk-accretion stage. The companion is located along the dark lane, consistent with it being in the equatorial/disk plane, indicating a disk-accretion setting for massive, multiple, star formation.

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Spatially resolving the accretion shocks on the rapidly-rotating M0 T-Tauri star MN Lupi

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We obtained high-resolution, high-quality VLT/UVES spectra to reconstruct the two-dimensional surface structure of the rapidly-rotating classical T-Tauri star MN Lupi on two separate nights. Both surface maps show a structured warm (5000 K) band centered around the pole at a latitude of $\sim 65^\circ$. Located within the band are two hot spots with temperatures of approximately or possibly even in excess of 5800 K, i.e. 2000 K above the effective photospheric temperature. Both maps appear with an adjacent equatorial band of temperature 3400 K, some 400-500 K below the effective photospheric temperature. While we interpret the two hot spots and the warm high-latitude band to be the heating points from two accretion impacts at the time of our observations and their redistributed energy trailed due to the fast stellar rotation, respectively, the cool equatorial band may not be cool after all but due to obscuration of the stellar surface by the innermost region of the disk. The fact that the hot spots appear at high stellar latitude is in agreement with the magnetospheric accretion model that proposes material funnelling onto the star along a predominantly dipolar magnetic field at roughly 50° latitude. The evidence of ongoing disk accretion, together with the very fast rotation of MN Lupi of just 3-4 times below its break-up velocity, suggests that the accretion mechanism is the cause of its rapid surface rotation. We present a model of magnetic star-disk coupling for MN Lupi that predicts a polar surface magnetic field of ~ 3 kG.

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The Origin of Planetary Impactors in the Inner Solar System

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Insights into the history of the inner solar system can be derived from the impact cratering record of the Moon, Mars, Venus, and Mercury and from the size distributions of asteroid populations. Old craters from a unique period of heavy bombardment that ended ~ 3.8 billion years ago were made by asteroids that were dynamically ejected from the main asteroid belt, possibly due to the orbital migration of the giant planets. The impactors of the past ~ 3.8 billion years have a size distribution quite different from that of the main belt asteroids but very similar to that of near-Earth asteroids.

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A Pre-Protostellar Core in L1551. II. State of Dynamical and Chemical Evolution

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Both analytic and numerical radiative transfer models applied to high spectral resolution CS and N₂H⁺ data give insight into the evolutionary state of L1551 MC. This recently discovered pre-protostellar core in L1551 appears to be in the early stages of dynamical evolution. Line-of-sight infall velocities of $> 0.1 \text{ km s}^{-1}$ are needed in the outer regions of L1551 MC to adequately fit the data. This translates to an accretion rate of $\sim 10^{-6} M_{\odot} \text{ yr}^{-1}$, uncertain to within a factor of 5 owing to unknown geometry. The observed dynamics are not due to spherically symmetric gravitational collapse and are not consistent with the standard model of low-mass star formation. The widespread, fairly uniform CS line asymmetries are more consistent with planar infall. There is modest evidence for chemical depletion in the radial profiles of CS and C¹⁸O suggesting that L1551 MC is also chemically young. The models are not very sensitive to chemical evolution. L1551 MC lies within a quiescent region of L1551 and is evidence for continued star formation in this evolved cloud.

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<http://arxiv.org/abs/astro-ph/0509817>

The Circumstellar Structure of the Class I Protostar TMC-1 (IRAS 04381+2540) from Hubble Space Telescope NICMOS Data

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The class I protostar TMC-1 (IRAS 04381+2540) located in the Taurus star-forming region is oriented favorably for determining the properties of its circumstellar envelope and outflow cavity. The conical nebulosity displays both a narrow jet and a wide-angle outflow. To fit the circumstellar structure of TMC-1 we compare Hubble Space Telescope NICMOS data at $1.6 \mu\text{m}$ with model images generated from a Monte Carlo scattering code. The models fit the intensity profile well, reproducing both the apparent width of the outflow cavity and the observed limb brightening. The main differences are a lack of observed emission from the rear of the outflow cavity, as well as small-scale structure from density fluctuations that is not accounted for in the axisymmetric models.

Previous work shows that the extended nebulosity seen around protostars at near-infrared wavelengths can be explained by stellar photons that scatter off circumstellar dust. The assumed density distribution for the model consists of the Terebey, Shu, and Cassen (1984) cloud collapse model (“infall envelope”), a conical outflow cavity, and a geometrically thin but opaque disk. The HST data show the outflow cavity is nearly conical and significantly wider than previously measured. The best fit model for TMC-1 has $45 \pm 5^{\circ}$ source inclination and $80 \pm 5^{\circ}$ deprojected wind opening angle (full width). The family of models that produce acceptable fits have parameters that are correlated such that models with a higher infall rate also have a higher inner mass. The disk size is not well constrained by these data except that large disks ($> 160 \text{ AU}$) are ruled out. The age, normally a poorly known quantity, is well constrained by the models. The protostar age, i.e. time since the onset of collapse, is $1 \times 10^5 \text{ yr}$ to within a factor of two.

We consider the efficiency of infall onto the protostar and find that plausible parameters can give an efficiency, and hence accretion luminosity, as low as 10% the value derived from the collapsing cloud core. The efficiency, together with a luminosity constraint, lead to a mass estimate that ranges from about $0.1 M_{\odot}$ for high efficiency to $0.2 M_{\odot}$ for low accretion efficiency onto the protostar. Similarly, the estimated mass accretion rate *onto the protostar* ranges from roughly $0.9 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$ to $1.4 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$, which is smaller than the $1.6 - 3.5 \times 10^{-6} M_{\odot} \text{ yr}^{-1}$ infall rate *of the cloud*. If low efficiency rates are prevalent for protostars, one important consequence is that it will take longer to assemble the central star than the time $t = M_{in}/\dot{M}_{in}$, a time that assumes *all* of the infalling material lands on the protostar.

Accepted by Astrophysical Journal

Induced planet formation in stellar clusters - a parameter study of star-disk encounters

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We present a parameter study of the possibility of tidally triggered disk instability. Using a restricted N-body model which allows for a survey of an extended parameter space, we show that a passing dwarf star with a mass between 0.1 and 1 M_{\odot} can probably induce gravitational instabilities in the pre-planetary solar disk for prograde passages with minimum separations below 80–170 AU for isothermal or adiabatic disks. Inclined and retrograde encounters lead to similar results but require slightly closer passages. Such encounter distances are quite likely in young moderately massive star clusters (Scally & Clarke 2001; Bonnell et al. 2001). The induced gravitational instabilities may lead to enhanced planetesimal formation in the outer regions of the protoplanetary disk, and could therefore be relevant for the existence of Uranus and Neptune, whose formation timescale of about 100 Myr (Wuchterl, Guillot & Lissauer 2000) is inconsistent with the disk lifetimes of about a few Myr according to observational data by Haisch, Lada & Lada (2001). The relatively small gas/solid ratio in Uranus and Neptune can be matched if the perturbing fly-by occurred after early gas depletion of the solar system, i.e. when the solar system was older than about 5 Myr.

We also confirm earlier results by Heller (1993) that the observed 7 degree tilt of the solar equatorial plane relative to the ecliptic plane could be the consequence of such a close encounter.

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Differentiation of the asteroid Ceres as revealed by its shape

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The accretion of bodies in the asteroid belt was halted nearly 4.6 billion years ago by the gravitational influence of the newly formed giant planet Jupiter. The asteroid belt therefore preserves a record of both this earliest epoch of Solar System formation and variation of conditions within the solar nebula. Spectral features in reflected sunlight indicate that some asteroids have experienced sufficient thermal evolution to differentiate into layered structures. The second most massive asteroid - 4 Vesta - has differentiated to a crust, mantle and core. 1 Ceres, the largest and most massive asteroid, has in contrast been presumed to be homogeneous, in part because of its low density, low albedo and relatively featureless visible reflectance spectrum, similar to carbonaceous meteorites that have suffered minimal thermal processing. Here we show that Ceres has a shape and smoothness indicative of a gravitationally relaxed object. Its shape is significantly less flattened than that expected for a homogeneous object, but is consistent with a central mass concentration indicative of differentiation. Possible interior configurations include water-ice-rich mantles over a rocky core.

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Flaring and self-shadowed disks around Herbig Ae stars: simulations for 10 μm interferometers

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We present simulations of the interferometric visibilities of Herbig Ae star disks. We investigate whether interferometric

measurements in the 10 μm atmospheric window are sensitive to the presence of an increased scale height at the inner disk edge, predicted by recent models. Furthermore, we investigate whether such measurements can discriminate between disks with a "flaring" geometry and disks with a "flat" geometry. We show that both these questions can be addressed, using measurements at a small number of appropriately chosen baselines. The classification of Herbig Ae stars in two groups, based on the appearance of the spectral energy distribution (SED), has been attributed to a difference in disk geometry. Sources with a group I SED would have a flaring outer disk geometry, whereas the disk of group II sources is proposed to be flat (or "self-shadowed"). We show that this hypothesis can be tested using long-baseline interferometric measurements in the 10 μm atmospheric window.

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Infrared and radio study of star forming regions associated with IRAS 19111+1048 and IRAS 19110+1045

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A multiwavelength study of the star forming regions associated with IRAS 19111+1048 and IRAS 19110+1045 has been carried out. These have been simultaneously mapped in two far infrared bands at $\lambda_{eff} = 130$ and 200 μm with $\sim 1'$ angular resolution using the TIFR 1-m balloon borne telescope. The radio emission from the ionised gas of these regions has been imaged at 1280, 610 and 325 MHz using the Giant Metrewave Radio Telescope, India. A total of 20 compact radio sources have been detected from the high resolution radio map of IRAS 19111+1048 at 1280 MHz (of which one is of non-thermal origin). Assuming these sources to represent exciting zero age main sequence (ZAMS) stars, the initial mass function [$\xi(m) \propto m^{-a}$] is found to be quite steep, with $a = 5.3 \pm 0.5$ for the mass range $14 < m/M_{\odot} < 33$. The near infrared (NIR) source coincident with the IRAS peak is likely to be an embedded pre-main sequence star. An attempt has been made to identify sources responsible for ionising the gas using NIR sources from 2MASS. The spectral types of the ZAMS stars inferred independently from the radio and NIR measurements match very well for a good fraction of the radio sources having NIR counterparts. For the IRAS 19110+1045 region, seven radio sources have been detected of which two are associated with deeply embedded 2MASS objects. Self consistent radiative transfer modelling aimed at extracting important physical and geometrical details of the two IRAS sources has been carried out using the above cluster of ZAMS stars as the central exciting sources. The best fit models are in good agreement with the observed spectral energy distributions. A uniform density distribution of dust and gas is implied for both the sources. The extents of ionised gas, number of ZAMS stars, presence of deeply embedded sources and lower value of L/M for the cloud, support the youth of IRAS 19110+1045 vis-a-vis its neighbour, IRAS 19111+1048, consistent with earlier studies.

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The paper is available as an Astro-ph preprint at
<http://arxiv.org/abs/astro-ph/0509869>

Chemical telemetry of OH observed to measure interstellar magnetic fields

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We present models for the chemistry in gas moving towards the ionization front of an HII region. When it is far from the ionization front, the gas is highly depleted of elements more massive than helium. However, as it approaches the ionization front, ices are destroyed and species formed on the grain surfaces are injected into the gas phase. Photodissociation removes gas phase molecular species as the gas flows towards the ionization front. We identify models for which the OH column densities are comparable to those measured in observations undertaken to study the

magnetic fields in star forming regions and give results for the column densities of other species that should be abundant if the observed OH arises through a combination of the liberation of H₂O from surfaces and photodissociation. They include CH₃OH, H₂CO, and H₂S. Observations of these other species may help establish the nature of the OH spatial distribution in the clouds, which is important for the interpretation of the magnetic field results.

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<http://arxiv.org/abs/astro-ph/0510087>

The effect of non-isothermality on the gravitational collapse of spherical clouds and the evolution of protostellar accretion

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We investigate the role of non-isothermality in gravitational collapse and protostellar accretion by explicitly including the effects of molecular radiative cooling, gas-dust energy transfer, and cosmic ray heating in models of spherical hydrodynamic collapse. Isothermal models have previously shown an initial decline in the mass accretion rate \dot{M} during the accretion phase of protostellar evolution, due to a gradient of infall speed that develops in the prestellar phase. Our results show that: (1) in the idealized limit of optically thin cooling, a positive temperature gradient is present in the prestellar phase which effectively cancels out the effect of the velocity gradient, producing a near constant (weakly increasing with time) \dot{M} in the early accretion phase; (2) in the more realistic case including cooling saturation at higher densities, \dot{M} may initially be either weakly increasing or weakly decreasing with time, for low dust temperature ($T_d \sim 6$ K) and high dust temperature ($T_d \sim 10$ K) cases, respectively. Hence, our results show that the initial decline in \dot{M} seen in isothermal models is definitely not enhanced by non-isothermal effects, and is often suppressed by them. In all our models, \dot{M} does eventually decline rapidly due to the finite mass condition on our cores and a resulting inward propagating rarefaction wave. Thus, any explanation for a rapid decline of \dot{M} in the accretion phase likely needs to appeal to the global molecular cloud structure and possible envelope support, which results in a finite mass reservoir for cores.

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Preprint available at <http://www.astro.uwo.ca/~basu/pb.html> and [astro-ph/0508428](http://arxiv.org/abs/astro-ph/0508428).

The Origin of Episodic Accretion Bursts in the Early Stages of Star Formation

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We study numerically the evolution of rotating cloud cores, from the collapse of a magnetically supercritical core to the formation of a protostar and the development of a protostellar disk during the main accretion phase. We find that the disk quickly becomes unstable to the development of a spiral structure similar to that observed recently in AB Aurigae. A continuous infall of matter from the protostellar envelope makes the protostellar disk unstable, leading to spiral arms and the formation of dense protostellar/protoplanetary clumps within them. The growing strength of spiral arms and ensuing redistribution of mass and angular momentum creates a strong centrifugal disbalance in the disk and triggers bursts of mass accretion during which the dense protostellar/protoplanetary clumps fall onto the central protostar. These episodes of clump infall may manifest themselves as episodes of vigorous accretion rate ($\geq 10^{-4} M_\odot \text{ yr}^{-1}$) as is observed in FU Orionis variables. Between these accretion bursts, the protostar is characterized by a low accretion rate ($< 10^{-6} M_\odot \text{ yr}^{-1}$). During the phase of episodic accretion, the mass of the protostellar disk remains less than or comparable to the mass of the protostar.

Accepted by ApJ Letters

Preprint available at <http://www.astro.uwo.ca/~basu/pb.html> and [astro-ph/0510014](http://arxiv.org/abs/astro-ph/0510014).

Observations of Global and Local Infall in NGC 1333

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We report “infall asymmetry” in the HCO⁺ (1–0) and (3–2) lines toward NGC 1333, extended over ~ 0.39 pc², a larger extent than has been reported before, for any star-forming region. The infall asymmetry extends over a major portion of the star-forming complex, and is not limited to a single protostar, or to a single dense core, or to a single spectral line. It seems likely that the infall asymmetry represents inward motions, and that these motions are physically associated with the complex. Both blue-asymmetric and red-asymmetric lines are seen, but in both the (3–2) and (1–0) lines of HCO⁺ the vast majority of the asymmetric lines are blue, indicating inward motions. The (3–2) line, tracing denser gas, has the spectra with the strongest asymmetry and these spectra are associated with the protostars IRAS 4A and 4B, which most likely indicates a warm central source is affecting the line profiles. The (3–2) and (1–0) lines usually have the same sense of asymmetry in common positions, but their profiles differ significantly, and the (1–0) line appears to trace motions on much larger spatial scales than does the (3–2) line. Line profile models fit the spectra well, but do not strongly constrain their parameters. The mass accretion rate of the inward motions is of order 10^{-4} M_⊙/yr, similar to the ratio of stellar mass to cluster age.

Accepted by ApJ.

Preprint available at: <http://arxiv.org/abs/astro-ph/0510066>

A high resolution comparative study of the slowly contracting, starless cores, L694-2 and L1544

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We present interferometric observations of N₂H⁺(1–0) in the starless, dense core L694-2 and compare them to previously published maps of L1544. Both cores are starless, centrally condensed, and show spectral signatures of rotation and collapse. We fit radially averaged spectra using a two-layer infall model and measure the variation of opacity and infall speed in each core. Both functions increase toward the center of each core but the radial gradients are shallower, and the central values lower, in L694-2. This general behavior is predicted in models of gravitational collapse with thermal plus magnetic support and the lower values in L694-2 may be due to its lower mass or a slightly earlier evolutionary state. In either case, it appears that both cores will form stars within a few 10⁴ yr.

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Hubble Space Telescope and United Kingdom Infrared Telescope Observations of the Center of the Trifid Nebula: Evidence for the Photoevaporation of a Proplyd and a Protostellar Condensation

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The Trifid Nebula (M20) is a well-known prominent optical H II region trisected by bands of obscuring dust lanes and excited by an O7.5 star, HD 164492A. Previous near-IR, mid-IR, and radio continuum observations of the cluster of stars at the center of the Trifid Nebula indicated the presence of circumstellar disks associated with hot stars

with envelopes that are photoionized externally by the UV radiation from the hot central star, HD 164492A. Using the WFPC2 on the Hubble Space Telescope, we present evidence of a resolved proplyd in H/α and [S II] line emission from a stellar source emitting cool dust emission. Using the United Kingdom Infrared Telescope, an infrared observation of the stellar source with a proplyd indicates a late F to mid-G spectral type. We also note a remarkable complex of filamentary and sheetlike structures that appear to arise from the edge of a protostellar condensation. These observations are consistent with a picture in which the bright massive star HD 164492A is responsible for the photoevaporation of protoplanetary disks of other less massive members of the cluster, as well as the closest protostellar condensation facing the central cluster. Using the evidence for a proplyd, we argue that the massive and intermediate-mass members of the cluster, HD 164492C (B6 star) and HD 164492 (Herbig Be star), have disks associated with them.

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Triggered massive-star formation on the borders of Galactic H II regions II. Evidence for the collect and collapse process around RCW 79

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We present SEST-SIMBA 1.2-mm continuum maps and ESO-NTT SOFI JHK_S images of the Galactic H II region RCW 79. The millimetre continuum data reveal the presence of massive fragments located in a dust emission ring surrounding the ionized gas. The two most massive fragments are diametrically opposite each other in the ring. The near-IR data, centred on the compact H II region located at the south-eastern border of RCW 79, show the presence of an IR-bright cluster containing massive stars along with young stellar objects with near-IR excesses. A bright near- and mid-IR source is detected towards maser emissions, 1.2 pc north-east of the compact H II region centre. Additional information extracted from the Spitzer GLIMPSE survey is used to discuss the nature of the bright IR sources observed towards RCW 79. Twelve luminous Class I sources are identified towards the most massive millimetre fragments. All these facts strongly indicate that the massive-star formation observed at the border of the H II region RCW 79 has been triggered by its expansion, most probably by the collect and collapse process.

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Origin and Ubiquity of Short-Period Earth-like Planets: Evidence for the Sequential Accretion Theory of Planet Formation

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The formation of gas giant planets is assumed to be preceded by the emergence of solid cores in the conventional sequential accretion paradigm. This hypothesis implies that the presence of Earth-like planets can be inferred from the detection of gas giants. A similar prediction cannot be made with the gravitational instability model, which assumes that gas giants formed from the collapse of gas fragments analogous to their host stars. We propose an observational test for the determination of the dominant planetary formation channel. Based on the sequential accretion model, we identify several potential avenues that may lead to the prolific formation of a population of close-in Earth-mass (M_{\oplus}) planets around stars with (1) short-period or (2) solitary eccentric giants and (3) systems that contain intermediate-

period resonant giants. In contrast, these close-in Earths are not expected to form in systems where giants originated rapidly through gravitational instability. As a specific example, we suggest that sequential accretion processes led to the formation of the $7.5 M_{\oplus}$ planet around GJ 876 and predict that it may have an atmosphere and envelope rich in O_2 and liquid water. Assessments of the ubiquity of these planets will lead to (1) the detection of the first habitable terrestrial planets, (2) verification of the dominant mode of planet formation, (3) an estimate of the fraction of stars harboring Earth-like planets, and (4) modification of biomarker signatures.

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Mass Flows in Cometary Ultracompact H II Regions

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High spectral and spatial resolution, mid-infrared fine-structure line observations toward two ultracompact H II (UC H II) regions (G29.96-0.02 and Mon R2) allow us to study the structure and kinematics of cometary UC H II regions. In our earlier study of Mon R2, we showed that highly organized mass motions accounted for most of the velocity structure in that UC H II region. In this work, we show that the kinematics in both Mon R2 and G29.96 are consistent with motion along an approximately paraboloidal shell. We model the velocity structure seen in our mapping data and test the stellar wind bow shock model for such paraboloidal-like flows. The observations and the simulation indicate that the ram pressures of the stellar wind and ambient interstellar medium cause the accumulated mass in the bow shock to flow along the surface of the shock. A relaxation code reproduces the mass flow's velocity structure as derived by the analytical solution. It further predicts that the pressure gradient along the flow can accelerate ionized gas to a speed higher than that of the moving star. In the original bow shock model, the star speed relative to the ambient medium was considered to be the exit speed of ionized gas in the shell.

Published by The Astrophysical Journal (Vol. 631, p. 381)

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Dissertation Abstracts

Dust distribution in protoplanetary disks

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Ph.D degree awarded: June 2005

The purpose of this work is to study the dust distribution in protoplanetary disks. It is important to interpret observations without making the questionable assumption that gas and dust are well mixed. It is also important for planet formation because it needs a density increase in the midplane.

In this work, we have studied the effect of aerodynamic drag, exerted by gas on dust, that slows it down and makes it settle to the midplane and spiral inwards.

We have first collaborated with D. Lin and P. Garaud (University of Santa Cruz, California, USA) on an analytical study of the collective motion of grains in the vertical direction under simplifying hypotheses.

We have then run numerical simulations using an SPH (Smooth Particles Hydrodynamics), two-fluid, locally isothermal, non self-gravitating and three-dimensional code describing a protoplanetary disk. We have thus followed quantitatively the settling of dust in a $0.01 M_{\odot}$ disk, made of 1% in mass of dust with grain size ranging from $1 \mu\text{m}$ to 10 μm , flowing around a $1 M_{\odot}$ star and extending from 0.5 to $\simeq 300$ astronomical units. We have thus shown that intermediate size grains settle to a layer with varying thickness to the midplane leading to an increase in their density that is favorable to planet formation.

Finally, we have applied our simulations to the case of GG Tau and produced, in collaboration with F. Ménard and C. Pinte (Grenoble Observatory, France), synthetic images in scattered light using the simulation results. Taking the settling into account makes it possible to reproduce observations in different wavelengths with a single size distribution.

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

Submillimeter Array Postdoctoral Fellowships Smithsonian Astrophysical Observatory

The Submillimeter Array (SMA), a collaborative project of the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan), is a radio-interferometer located at an altitude of 4,000 m near the summit of Mauna Kea, Hawaii. It consists of eight six-meter diameter antennas configurable to achieve sub arc second resolution, and is now in routine operation in two low-frequency atmospheric windows, centered at 220 and 300 GHz, and a high frequency window at 650 GHz. During the coming year it will be equipped with receivers that will extend the low frequency coverage up to 430 GHz; and enable enhanced polarization capability throughout the 330-350 GHz frequency range. For more information about the SMA, see <http://sma-www.cfa.harvard.edu>

Applications are invited for two SMA postdoctoral fellowships beginning in the fall of 2006. Fellowships are for a period of two years, with the possibility of a one-year extension. These positions are aimed chiefly at research in submillimeter astronomy, and the successful candidates are expected to propose and participate in science observations with the SMA. The current major areas of study include: *the formation, kinematics, and chemistry of protostellar disks and outflows*; AGN's, including the Galactic Center; circumstellar material around evolved stars; the structure and energetics of normal and luminous galaxies; and solar system studies. It is expected that both positions will be based at the Harvard Smithsonian Center for Astrophysics in Cambridge to facilitate interaction with other scientists within the Radio division and the wider CfA community. However, candidates with a desire to be located at the SMA facility at the University of Hawaii, Hilo, are also encouraged to apply.

Applicants must have a recent Ph.D. in astronomy or a related field. Practical experience in millimeter or submillimeter wavelength astronomy, radio interferometry, instrumentation, or experience in any applicable branch of astrophysical theory is desirable. Questions should be directed to David Wilner, dwilner@cfa.harvard.edu. Applications, including a curriculum vita, statement of research interest, and three letters of recommendation should be sent to J. Barnett before 31 December 2005 for full consideration. Note that applicants for other CfA fellowships are not automatically forwarded to the SMA Fellowship Selection Committee. AAE/EOE

Submission Address for Resumes/CVs:

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Two PhD thesis projects in Massive Star Formation employing state of the art (Sub)Millimeter Interferometry

The Emmy-Noether Research Group "The Formation of Massive Stars" at the Max-Planck-Institute for Astronomy (MPIA) offers two PhD thesis projects. Both projects are in the field of massive star formation using state of the art (Sub)Millimeter Wavelength Interferometers. Massive star formation is one of the most lively evolving parts of star formation research where many exiting questions remain to be tackled. One of the main underlying question in massive star formation is whether the most massive stars form via similar physical processes like their low-mass counterparts, or whether completely different processes, for example, the coalescence and merging of intermediate-mass protostars, are important as well. The availability of (Sub)Millimeter Interferometers - already existing instruments as well as future arrays (e.g., PdBI, SMA, CARMA, ALMA) - now allows to resolve the innermost regions of massive star-forming regions and thus study the physical processes in detail. The two thesis projects will focus on very different questions in the field of massive star formation but nevertheless their ultimate goals - understanding the physics in massive star formation - and the observational and theoretical tools are similar. Therefore, it is expected that the two PhD candidates collaborate with each other and learn from the others work.

Thesis 1: Disks in massive star formation

The last few years have accumulated large amounts of indirect evidence that at least early B and late O stars (up to probably 20Msun) form via similar disk-accretion proecesses like their low-mass counterparts. However, all these studies were rather indirect, and the time is ripe to investigate the underlying expected accretion disks in more detail. The advent of the above mentioned (sub)mm intereferometers now allows for the first time to resolve the dense gas and dust around the central massive protostars, and hence carefully tackle these questions investigating the small-scale structure of the massive star-forming regions. Furthermore, even the most massive stars (up to 100Msun) may harbor massive disks, but their physics could be very different to their low-mass counterparts changing the actual accretion processes. This thesis project is expected to observe a sample of massive disk candidates, and investigate the physical properties and the evolution of these objects. A potential evolutionary sequence as well as expetected differences between disks around objects of different masses are possible exciting perspectives of this project. The understanding of massive accretion disks is often considered as the missing link in the understanding of massive star formation.

Thesis 2: Fragmentation of massive star-forming clusters

The Initial Mass Function (IMF), i.e., the universal mass distribution of cluster stars and field stars, is one of the fundamental observational properties of almost all observed stellar distributions. However, until today it is not clear why the IMF is universal and at what time of the stellar cluster evolution the IMF forms. Since almost all massive stars form in a clustered mode, massive star-forming regions are the ideal environment to study the early evolution of the IMF. Furthermore, the two main theories of massive star formation - disk accretion and early fragmentation of the massive gas cores versus the coalescence and merging model - predict different shapes of the protocluster mass functions at early evolutionary stages. To resolve the dense gas and dust of the deeply embedded very young massive star-forming clusters, high-spatial resolution in the (sub)mm wavelength regime is necessary, thus requiring again (sub)mm interferometric observations. The thesis candidate is expected to observe various young massive star-forming regions in different evolutionary stages. The analysis of a statistically significant sample should allow to derive protocluster mass functions of the different regions and thus constrain whether the IMF is determined at the very beginning of massive star formation or whether different processes during the cluster formation process contribute to the shape of the IMF. To solve the formation history of such an important universal characteristic like the IMF will be an exciting overall goal of this project.

Requirements and organizational outline

The PhD candidates should hold the equivalent of a Master of Science in astronomy or physics (Dipl.-Phys.) and ideally have first experiences with observational research of star-forming regions and/or the interstellar medium.

The anticipated three years duration of their PhD time is expected to be split up between the Max-Planck-Institute for Astronomy in Heidelberg/Germany and the Harvard-Smithsonian Center for Astrophysics in Cambridge/USA. The students will stay the first year in Heidelberg, get accustomed to the current status of massive star formation research, learn the techniques of (sub)mm interferometry and define the specific goals of their thesis work. Furthermore, they are expected to write observation proposals and acquire new data. The 2nd year of their thesis projects, the students are supposed to stay at the Havard-Smithsonian Center for Astrophysics (CfA) in Cambridge/USA. The CfA is the largest astrophysical institute of the world and leads the Submillimeter Array project (SMA) on Mauna Kea/Hawaii.

Getting first hand expertise with the only currently existing Submillimeter Interferometer allows the PhD students to gain invaluable expertise in this field and set the stage for the future array ALMA. In addition to Henrik Beuther at the MPIA, the students will have a complementary supervisor at the CfA for that year. Nevertheless, to accomodate the necessary exchange between them and Henrik Beuther, visits between the MPIA and the CfA will take place during that time. The third year of their thesis projects, the candidates will return back to Heidelberg. By that time, they will have considerable experience and results in massive star formation research and (sub)mm interferometry, they will likely be in the process of publishing their work in renowned scientific journals, and they are expected to refine their analysis and finalize their thesis.

Interested students are invited to send an application including a curriculum vitae, copies of University degrees/records, and two letters of recommendation to

MAX-PLANCK INSTITUTE FOR ASTRONOMY
Personnel Department
Koenigstuhl 17
Heidelberg, D-69117
Germany

Informal inquires can be sent to Henrik Beuther, Email: beuther@mpia-hd.mpg.de, Tel.: +49 (0)6221 528 407. More information is available at <http://www.mpia.de/homes/beuther/phd.html>.

Applications received before Dec. 31, 2005 will receive fullest consideration. Later applications will be considered on the basis of availability. This positions will be open until a suitable candidate is found.

The MPIA is an equal opportunity employer. Applications from women and historically under-represented groups are particularly welcome.

Postdoctoral Position in Star Formation Dublin City University, Ireland

A two year postdoctoral position is available to work on a joint Dublin City University and Dublin Institute for Advanced Studies project in star formation as part of the CosmoGrid consortium (<http://www.cosmogrid.ie/>). The successful candidate will be expected to use computational techniques to study aspects of the process of star formation, and/or its effects on the local environment. This consortium has access to excellent computational facilities, both through its own 220 node cluster, as well as a 40% share in the resources of the Irish Centre for High-End Computing, along with several smaller clusters. Ideally, the successful candidate would have a background in astrophysical numerical simulations. Candidates must have a PhD, or have recently submitted their thesis.

The position will be paid in the range 31,102 - 40,146 Euro per annum depending upon experience. Application is by letter and CV naming 3 academic referees. The letter should contain a description of research interests. The closing date for applications is Friday 11th November, 2005. Letters of application and CVs should be sent to: Dr. Turlough Downes, School of Mathematical Sciences, Dublin City University, Glasnevin, Dublin 9, Ireland, or by email to turlough.downes@dcu.ie.

For further details please contact Dr. Downes, at the above address.

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Meetings

RTN School on Jets from Young Stars: Models and Constraints

Submitted by: Jonathan Ferreira, Catherine Dougados

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This school will be held at Villard-de-Lans (near Grenoble in France), from 9 to 13 January 2006. The school is dedicated to jets from Young Stars with a focus on the various MagnetoHydroDynamic (MHD) theoretical models used to describe them. This is the first school in a series of five organized by the European Marie Curie research training network JETSET (Jet Simulations, Experiments and Theories). Forthcoming schools will cover the following aspects : II- High Angular Resolution and Interferometric Technics Applied to Jets, III- Numerical MHD and Instabilities, IV- Grid Technology and Applications to Astrophysics, V- From Models to Observations and Experiments.

The aim of the first school is to provide a solid background in MHD as well as a good knowledge on the overall jet observational properties. It is therefore recommended to attend it in order to get the basis for the following schools. The number of participants is limited to 70. The school is open to postgraduate students and young researchers outside the network. Limited support may be available for such participants (preference will be given to those proposing a poster or an oral contribution).

Deadline for registration is November 10, 2005. Registration form and further information can be found at the following address: <http://www.jetsets.org/grenoble.html>