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Abstracts of recently accepted papers

Gravity or Turbulence? The velocity dispersion-size relation

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We discuss the nature of the velocity dispersion vs. size relation for molecular clouds. In particular, we add to previous observational results showing that the velocity dispersions in molecular clouds and cores are not purely functions of spatial scale but involve surface gas densities as well. We emphasize that hydrodynamic turbulence is required to produce the first condensations in the progenitor medium. However, as the cloud is forming, it also becomes bound, and gravitational accelerations dominate the motions. Energy conservation in this case implies $|E_g| \sim E_k$, in agreement with observational data, and providing an interpretation for two recent observational results: the scatter in the $\delta v - R$ plane, and the dependence of the velocity dispersion on the surface density $\delta v^2/R \propto \Sigma$. We argue that the observational data are consistent with molecular clouds in a state of hierarchical gravitational collapse, i.e., developing local centers of collapse throughout the whole cloud while the cloud itself is collapsing, and making equilibrium unnecessary at all stages prior to the formation of actual stars. Finally, we discuss how this mechanism need not be in conflict with the observed star formation rate.

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New constraints on dust grain size and distribution in CQ Tau

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Grain growth in circumstellar disks is expected to be the first step towards the formation of planetary systems. There is now evidence for grain growth in several disks around young stars. Radially resolved images of grain growth in circumstellar disks are believed to be a powerful tool to constrain the dust evolution models and the initial stage for the formation of planets. In this paper we attempt to provide these constraints for the disk surrounding the young star CQ Tau. This system was already suggested from previous studies to host a population of grains grown to large sizes. We present new high angular resolution ($0''.3-0''.9$) observations at wavelengths from 850 μm to 3.6 cm obtained at the SMA, IRAM-PdBI and NRAO-VLA interferometers. We perform a combined analysis of the spectral energy distribution and of the high-resolution images at different wavelengths using a model to describe the dust thermal emission from the circumstellar disk. We include a prescription for the gas emission from the inner regions of the system. We detect the presence of evolved dust by constraining the disk averaged dust opacity coefficient β (computed between 1.3 and 7 mm) to be 0.6 ± 0.1. This confirms the earlier suggestions that the disk contains dust grains grown to significant sizes and puts this on firmer grounds by tightly constraining the gas contamination to the observed fluxes at mm-cm wavelengths. We report some evidence of radial variations in dust properties, but current resolution and sensitivity are still too low for definitive results.

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Effect of episodic accretion on the structure and the lithium depletion of low-mass stars and planet-hosting stars

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Following up our recent analysis devoted to the impact of non steady accretion on the location of young low-mass stars or brown dwarfs in the Herzsprung-Russell diagram, we perform a detailed analysis devoted to the effect of burst accretion on the internal structure of low-mass and solar type stars. We find that episodic accretion can produce objects with significantly higher central temperatures than the ones of the non accreting counterparts of same mass and age. As a consequence, lithium depletion can be severely enhanced in these objects. This provides a natural explanation for the unexpected level of lithium depletion observed in young objects for the inferred age of their parent cluster. These results confirm the limited reliability of lithium abundance as a criterion for assessing or rejecting cluster membership. They also show that lithium is not a reliable age indicator, because its fate strongly depends on the past accretion history of the star. Under the assumption that giant planets primarily form in massive disks prone to gravitational instability and thus to accretion burst episodes, the same analysis also explains the higher Li depletion observed in planet hosting stars. At last, we show that, depending on the burst rate and intensity, accretion outbursts can produce solar mass stars with lower convective envelope masses, at ages less than a few tens of Myr, than predicted by standard (non or slowly accreting) pre-main sequence models. This result has interesting, although speculative, implications for the recently discovered depletion of refractory elements in the Sun.

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VLA observations of water masers towards 6.7 GHz methanol maser sources

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22 GHz water and 6.7 GHz methanol masers are usually thought as signposts of early stages of high-mass star formation but little is known about their associations and the physical environments they occur in. The aims of the project were to obtain accurate positions and morphologies of the water maser emission and relate them to the methanol maser emission recently mapped with Very Long Baseline Interferometry. A sample of 31 methanol maser sources was searched for 22 GHz water masers using the VLA and observed in the 6.7 GHz methanol maser line with the

32 m Torun dish simultaneously. Water maser clusters were detected towards 27 sites finding 15 new sources. The detection rate of water maser emission associated with methanol sources was as high as 71%. In a large number of objects (18/21) the structure of water maser is well aligned with that of the extended emission at 4.5 μm confirming the origin of water emission from outflows. The sources with methanol emission with ring-like morphologies, which likely trace a circumstellar disk/torus, either do not show associated water masers or the distribution of water maser spots is orthogonal to the major axis of the ring. The two maser species are generally powered by the same high-mass young stellar object but probe different parts of its environment. The morphology of water and methanol maser emission in a minority of sources is consistent with a scenario that 6.7 GHz methanol masers trace a disc/torus around a protostar while the associated 22 GHz water masers arise in outflows. The majority of sources in which methanol maser emission is associated with the water maser appears to trace outflows. The two types of associations might be related to different evolutionary phases.

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available on astro-ph: http://arxiv.org/abs/1009.2334

Spatially Extended Brackett Gamma Emission in the Environments of Young Stars

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The majority of atomic hydrogen Brγ emission detected in the spectra of young stellar objects (YSOs) is believed to arise from the recombination regions associated with the magnetospheric accretion of circumstellar disk material onto the forming star. In this paper, we present the results of a K-band IFU spectroscopic study of Brγ emission in eight young protostars: CW Tau, DG Tau, Haro 6-10, HL Tau, HV Tau C, RW Aur, T Tau and XZ Tau. We spatially resolve Brγ emission structures in half of these young stars and find that most of the extended emission is consistent with the location and velocities of the known Herbig-Haro flows associated with these systems. At some velocities through the Brγ line profile, the spatially extended emission comprises 20% or more of the integrated flux in that spectral channel. However, the total spatially extended Brγ is typically less than $\sim$10% of the flux integrated over the full emission profile. For DG Tau and Haro 6-10 S, we estimate the mass outflow rate using simple assumptions about the hydrogen emission region, and compare this to the derived mass accretion rate. We detect extended Brγ in the vicinity of the more obscured targets in our sample and conclude that spatially extended Brγ emission may exist toward other stars, but unattenuated photospheric flux probably limits its detectability.

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On The Possibility of Enrichment and Differentiation in Gas Giants During Birth by Disk Instability

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We investigate the coupling between rock-size solids and gas during the formation of gas giant planets by disk fragmentation in the outer regions of massive disks. In this study, we use three-dimensional radiative hydrodynamics simulations and model solids as a spatial distribution of particles. We assume that half of the total solid fraction is in small grains and half in large solids. The former are perfectly entrained with the gas and set the opacity in the disk, while the latter are allowed to respond to gas drag forces, with the back reaction on the gas taken into account. To explore the maximum effects of gas-solid interactions, we first consider 10cm-size particles. We then compare these results to a simulation with 1 km-size particles, which explores the low-drag regime. We show that (1) disk instability planets have the potential to form large cores due to aerodynamic capturing of rock-size solids in spiral arms before fragmentation; (2) that temporary clumps can concentrate tens of $M_\oplus$ of solids in very localized regions before clump disruption; (3) that the formation of permanent clumps, even in the outer disk, is dependent on the grain-size distribution, i.e., the opacity; (4) that nonaxisymmetric structure in the disk can create disk regions that have a solids-to-gas ratio greater than unity; (5) that the solid distribution may affect the fragmentation process; (6) that proto-gas giants and proto-brown dwarfs can start as differentiated objects prior to the H_2 collapse phase; (7) that spiral arms in a gravitationally unstable disk are able to stop the inward drift of rock-size solids, even redistributing them to larger radii; and, (8) that large solids can form spiral arms that are offset from the gaseous spiral arms. We conclude that planet embryo formation can be strongly affected by the growth of solids during the earliest stages of disk accretion.

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The Spatial Distribution of Star Formation in the Solar Neighbourhood: Do all stars form in dense clusters?

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We present a global study of low mass, young stellar object (YSO) surface densities (Σ) in nearby (< 500 pc) star forming regions based on a comprehensive collection of *Spitzer Space Telescope* surveys. We show that the distribution of YSO surface densities in the solar neighbourhood is a smooth distribution, being adequately described by a lognormal function from a few to 10^3 YSOs per pc^2, with a peak at ~ 22 stars pc^{-2} and a dispersion of $\sigma_{\log_{10}\Sigma} \sim 0.85$. We do not find evidence for multiple discrete modes of star-formation (e.g. clustered and distributed). Comparing the observed surface density distribution to previously reported surface density threshold definitions of clusters, we find that the fraction of stars in clusters is crucially dependent on the adopted definitions, ranging from 40 to 90%. However, we find that only a low fraction (< 26%) of stars are formed in dense environments where their formation/evolution (along with their circumstellar disks and/or planets) may be affected by the close proximity of their low-mass neighbours.

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N_2H^+ depletion in the massive protostellar cluster AFGL 5142

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Aims. We aim at investigating with high angular resolution the NH_3/N_2H^+ abundance ratio toward the high-mass star-forming region AFGL 5142 in order to study whether the NH_3/N_2H^+ ratio behaves similarly to the low-mass case, for which the ratio decreases from starless cores to cores associated with young stellar objects (YSOs).
Methods. CARMA was used to observe the 3.2 mm continuum and N_2H^+ (1–0) emission toward AFGL 5142. We used NH_3 (1,1) and (2,2), as well as HCO^+ (1–0) and $H^{13}CO^+$ (1–0) data available from the literature to study the chemical environment. Additionally we performed a time-dependent chemical modeling of the region.
Results. The 3.2 mm continuum emission reveals a dust condensation of ~ 23 mo associated with the massive YSOs, deeply embedded in the strongest NH_3 core (hereafter central core). The dense gas emission traced by N_2H^+ reveals two main cores, the western core of ~ 0.08 pc in size and the eastern core of ~ 0.09 pc, surrounded by a more extended and complex structure of ~ 0.5 pc, mimicking the morphology of the NH_3 emission. The two cores are located to the west and to the east of the 3.2 mm dust condensation. Toward the central core the N_2H^+ emission drops significantly, indicating a clear chemical differentiation in the region. The N_2H^+ column density in the central core is one order of magnitude lower than in the western and eastern cores. Furthermore, we found low values of the NH_3/N_2H^+ abundance ratio ∼50–100 toward the western and eastern cores, and high values up to 1000 associated with the central core. The chemical model used to explain the differences seen in the NH_3/N_2H^+ ratio indicates that density, and in particular temperature, are key parameters in determining the abundances of both NH_3 and N_2H^+. The high density ($n \simeq 10^6$ cm^{-3}) and temperature ($T \simeq 70$ K) reached in the central core allow molecules such as CO to evaporate from grain mantles. The CO desorption causes a significant destruction of N_2H^+, which favors the formation of HCO^+. This result is supported by our observations, which show that N_2H^+ and HCO^+ are anticorrelated in the central core. The observed values of the NH_3/N_2H^+ ratio in the central core can be reproduced by our model for times $t \simeq 4.5 - 5.3 \times 10^5$ yr while in the western and eastern cores the NH_3/N_2H^+ ratio can be reproduced by our model for times in the range $10^4 - 3 \times 10^6$ yr.
Conclusions. The NH_3/N_2H^+ abundance ratio in AFGL 5142 does not follow the same trend as in regions of low-mass star formation mainly due to the high temperature reached in hot cores.

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Water vapor toward starless cores: the *Herschel* view

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Aims. Previous studies by the satellites SWAS and Odin provided stringent upper limits on the gas phase water abundance of dark clouds ($x(H_2O) < 7 \times 10^{-9}$). We investigate the chemistry of water vapor in starless cores beyond the previous upper limits using the highly improved angular resolution and sensitivity of *Herschel* and measure the

abundance of water vapor during evolutionary stages just preceding star formation.
Methods. High spectral resolution observations of the fundamental ortho water (o-H_2O) transition (557 GHz) were carried out with the Heterodyne Instrument for the Far Infrared onboard *Herschel* toward two starless cores: Barnard 68 (hereafter B68), a Bok globule, and LDN 1544 (L1544), a prestellar core embedded in the Taurus molecular cloud complex. Detailed radiative transfer and chemical codes were used to analyze the data.
Results. The rms in the brightness temperature measured for the B68 and L1544 spectra is 2.0 and 2.2 mK, respectively, in a velocity bin of 0.59 km s^{-1}. The continuum level is 3.5±0.2 mK in B68 and 11.4±0.4 mK in L1544. No significant feature is detected in B68 and the 3 σ upper limit is consistent with a column density of o-H_2O N(o-H_2O) $< 2.5\times10^{13}$ cm^{-2}, or a fractional abundance x(o-H_2O) $< 1.3\times10^{-9}$, more than an order of magnitude lower than the SWAS upper limit on this source. The L1544 spectrum shows an absorption feature at a 5 σ level from which we obtain the first value of the o-H_2O column density ever measured in dark clouds: N(o-H_2O) = $(8\pm4)\times10^{12}$ cm^{-2}. The corresponding fractional abundance is x(o-H_2O) $\simeq 5\times10^{-9}$ at radii > 7000 AU and $\simeq2\times10^{-10}$ toward the center. The radiative transfer analysis shows that this is consistent with a x(o-H_2O) profile peaking at $\simeq10^{-8}$, 0.1 pc away from the core center, where both freeze-out and photodissociation are negligible.
Conclusions. *Herschel* has provided the first measurement of water vapor in dark regions. Column densities of o-H_2O are low, but prestellar cores such as L1544 (with their high central densities, strong continuum, and large envelopes) appear to be very promising tools to finally shed light on the solid/vapor balance of water in molecular clouds and oxygen chemistry in the earliest stages of star formation.

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Outflows and mass accretion in collapsing dense cores with misaligned rotation axis and magnetic field

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Outflows and jets are intimately related to the formation of stars, and play an important role in redistributing mass, energy and angular momentum within the dense core and parent cloud. The interplay between magnetic field and rotation is responsible for launching these outflows, whose formation has been generally carried out for idealized systems where the angle α between the rotation axis and large-scale magnetic field is zero. Here we explore, through three-dimensional ideal magneto-hydrodynamic simulations, the effects of a non-zero α on the formation of outflows during the collapse of dense pre-stellar cores. We find that mass ejection is less efficient for increasing angle α, and that outflows are essentially suppressed for $\alpha \sim 90°$. An important consequence is a corresponding increase of the mass accreted onto the adiabatic (first) core. In addition, mean flow velocities tend to increase with α, and misaligned configurations produce clumpy, heterogeneous outflows that undergo precession, and are more prone to instabilities.

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Star Clusters Under Stress: Why Small Systems Cannot Dynamically Relax

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Utilizing a series of N-body simulations, we argue that gravitationally bound stellar clusters of modest population evolve very differently from the picture presented by classical dynamical relaxation theory. The system's most massive stars rapidly sink toward the center and form binary systems. These binaries efficiently heat the cluster, reversing any incipient core contraction and driving a subsequent phase of global expansion. Most previous theoretical studies demonstrating deep and persistent dynamical relaxation have either conflated the process with mass segregation, ignored three-body interactions, or else adopted the artificial assumption that all cluster members are single stars of identical mass. In such a uniform-mass cluster, binary formation is greatly delayed, as we confirm here both

numerically and analytically. The relative duration of core contraction and global expansion is affected by stellar evolution, which causes the most massive stars to die out before they form binaries. In clusters of higher N, the epoch of dynamical relaxation lasts for progressively longer periods. By extrapolating our results to much larger populations, we can understand, at least qualitatively, why some globular clusters reach the point of true core collapse.

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Herschel observations of EXtra-Ordinary Sources: The Terahertz spectrum of Orion KL seen at high spectral resolution

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We present the first high spectral resolution observations of Orion KL in the frequency ranges 1573.4 – 1702.8 GHz (band 6b) and 1788.4 – 1906.8 GHz (band 7b) obtained using the HIFI instrument on board the *Herschel* Space Observatory. We characterize the main emission lines found in the spectrum, which primarily arise from a range of components associated with Orion KL including the hot core, but also see widespread emission from components associated with molecular outflows traced by H_2O, SO_2, and OH. We find that the density of observed emission lines is significantly diminished in these bands compared to lower frequency *Herschel*/HIFI bands.

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Detailed polarimetric properties of the Pipe Nebula at Core Scales

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We use R-band CCD linear polarimetry collected for about 12 000 background field stars in 46 fields of view toward the Pipe nebula to investigate the properties of the polarization across this dark cloud. Based on archival 2MASS data we estimate that the surveyed areas present total visual extinctions in the range $0.6mag \leq A_V \leq 4.6mag$. While the observed polarizations show a well ordered large scale pattern, with polarization vectors almost perpendicularly aligned to the cloud's long axis, at core scales one see details that are characteristics of each core. Although many observed stars present degree of polarization which are unusual for the common interstellar medium, our analysis suggests that the dust grains constituting the diffuse parts of the Pipe nebula seem to have the same properties as the normal Galactic interstellar medium. Estimates of the second–order structure function of the polarization angles suggest that most of the Pipe nebula is magnetically dominated and that turbulence is sub-Alvénic. The Pipe nebula is certainly an interesting region where to investigate the processes prevailing during the initial phases of low mass stellar formation.

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Young Starless Cores Embedded in the Magnetically Dominated Pipe

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The Pipe Nebula is a massive, nearby dark molecular cloud with a low star-formation efficiency which makes it a good laboratory to study the very early stages of the star formation process. The Pipe Nebula is largely filamentary, and appears to be threaded by a uniform magnetic field at scales of few parsecs, perpendicular to its main axis. The field is only locally perturbed in a few regions, such as the only active cluster forming core B59. The aim of this study is to investigate primordial conditions in low-mass pre-stellar cores and how they relate to the local magnetic field in the cloud. We used the IRAM 30-m telescope to carry out a continuum and molecular survey at 3 and 1 mm of early- and late-time molecules toward four selected starless cores inside the Pipe Nebula. We found that the dust continuum emission maps trace better the densest regions than previous 2MASS extinction maps, while 2MASS extinction maps trace better the diffuse gas. The properties of the cores derived from dust emission show average radii of $\sim$0.09 pc, densities of $\sim 1.3\times10^5$ cm^{-3}, and core masses of $\sim$2.5 $M_\odot$. Our results confirm that the Pipe Nebula starless cores studied are in a very early evolutionary stage, and present a very young chemistry with different properties that allow us to propose an evolutionary sequence. All of the cores present early-time molecular emission, with CS detections toward all the sample. Two of them, Cores 40 and 109, present strong late-time molecular emission. There seems to be a correlation between the chemical evolutionary stage of the cores and the local magnetic properties that suggests that the evolution of the cores is ruled by a local competition between the magnetic energy and other mechanisms, such as turbulence.

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Discovery of "isolated" comoving T Tauri stars in Cepheus

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Context. During the course of a large spectroscopic survey of X-ray active late-type stars in the solar neighbourhood, we discovered four lithium-rich stars packed within just a few degrees on the sky. Although located in a sky area rich in CO molecular regions and dark clouds, the Cepheus-Cassiopeia complex, these very young stars are projected several degrees away from clouds in front of an area void of interstellar matter. As such, they are very good "isolated" T Tauri star candidates.
Aims. We present optical observations of these stars conducted with 1–2 meter class telescopes. We acquired high-resolution optical spectra as well as photometric data allowing us to investigate in detail their nature and physical parameters with the aim of testing the "runaway" and "in-situ" formation scenarios. Their kinematical properties are also analyzed to investigate their possible connection to already known stellar kinematic groups.
Methods. We use the cross-correlation technique and other tools developed by us to derive accurate radial and rotational velocities and perform an automatic spectral classification. The spectral subtraction technique is used to infer chromospheric activity level in the Hα line core and clean the spectra of photospheric lines before measuring the equivalent width of the lithium absorption line.
Results. Both physical (lithium content, chromospheric, and coronal activities) and kinematical indicators show that all stars are very young, with ages probably in the range 10–30 Myr. In particular, the spectral energy distribution of TYC 4496-780-1 displays a strong near- and far-infrared excess, typical of T Tauri stars still surrounded by an accretion disc. They also share the same Galactic motion, proving that they form a homogeneous moving group of stars with the same origin.
Conclusions. The most plausible explanation of how these "isolated" T Tauri stars formed is the "in-situ" model,

although accurate distances are needed to clarify their connection with the Cepheus-Cassiopeia complex. The discovery of this loose association of "isolated" T Tauri stars can help to shed light on atypical formation processes of stars and planets in low-mass clouds.

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Detection of OH^+ and H_2O^+ towards Orion KL

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We report observations of the reactive molecular ions OH^+, H_2O^+, and H_3O^+ towards Orion KL with Herschel/HIFI. All three $N = 1 - 0$ fine-structure transitions of OH^+ at 909, 971, and 1033 GHz and both fine-structure components of the doublet *ortho*-H_2O^+ $1_{11} - 0_{00}$ transition at 1115 and 1139 GHz were detected; an upper limit was obtained for H_3O^+. OH^+ and H_2O^+ are observed purely in absorption, showing a narrow component at the source velocity of 9 km s^{-1}, and a broad blueshifted absorption similar to that reported recently for HF and *para*-$H_2^{18}O$, and attributed to the low velocity outflow of Orion KL. We estimate column densities of OH^+ and H_2O^+ for the 9 km s^{-1} component of $9 \pm 3 \times 10^{12}$ cm^{-2} and $7 \pm 2 \times 10^{12}$ cm^{-2}, and those in the outflow of $1.9 \pm 0.7 \times 10^{13}$ cm^{-2} and $1.0 \pm 0.3 \times 10^{13}$ cm^{-2}. Upper limits of 2.4×10^{12} cm^{-2} and 8.7×10^{12} cm^{-2} were derived for the column densities of *ortho* and *para*-H_3O^+ from transitions near 985 and 1657 GHz. The column densities of the three ions are up to an order of magnitude lower than those obtained from recent observations of W31C and W49N. The comparatively low column densities may be explained by a higher gas density despite the assumption of a very high ionization rate.

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The Light Curve of the Weakly-Accreting T Tauri Binary KH 15D from 2005-10: Insights into the Nature of its Protoplanetary Disk

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Photometry of the unique pre-main sequence binary system KH 15D is presented, spanning the years 2005-2010. This system has exhibited photometric variations and eclipses over the last ∼50 years that are attributed to the effect of a precessing circumbinary disk. Advancement of the occulting edge across the projection on the sky of the binary orbit has continued and the photospheres of both stars are now completely obscured at all times. The system has thus transitioned to a state in which it should be visible only by scattered light, and yet it continues to show a periodic variation on the orbital cycle with an amplitude exceeding two magnitudes. This variation, which depends only on the binary phase and not on the height of either star above or below the occulting edge, has likely been present in the data since at least 1995. It can, by itself, account for the "shoulders" on the light curve prior to ingress and following egress, obviating to some degree the need for components of extant models such as a scattering halo around star A or forward scattering from a fuzzy disk edge. However, the spectroscopic evidence for some direct or forward scattered light from star A even when it was several stellar radii below the occulting edge shows that these components can probably not be fully removed, and raises the possibility that the occulting edge is currently more opaque than it was a decade ago, when the spectra were obtained. A plausible source for the variable scattering component is reflected light from the far side of a warped occulting disk. We have detected color changes in V-I of several tenths of a magnitude to both the blue and red that occur during times of minima. These may indicate the presence of a third source of light (faint star) within the system, or a change in the reflectance properties of the disk as the portion being illuminated varies with the orbital motion of the stars. The data support a picture of the circumbinary disk as a geometrically thin, optically thick layer of perhaps mm or cm-sized particles that has been sculpted by the binary stars and possibly other components into a decidedly nonplanar configuration. A simple (infinitely sharp) knife-edge model does a good job of accounting for all of the recent (2005-2010) occultation data when one allows for the scattered light component, the spottedness of Star A and variations from cycle to cycle in the location of the edge at the level of 0.1-0.2 stellar

diameters.

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Nitrogen hydrides in the cold envelope of IRAS16293-2422

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Nitrogen is the fifth most abundant element in the Universe, yet the gas-phase chemistry of N-bearing species remains poorly understood. Nitrogen hydrides are key molecules of nitrogen chemistry. Their abundance ratios place strong constraints on the production pathways and reaction rates of nitrogen-bearing molecules. We observed the class 0 protostar IRAS16293-2422 with the heterodyne instrument HIFI, covering most of the frequency range from 0.48 to 1.78 THz at high spectral resolution. The hyperfine structure of the amidogen radical o-NH_2 is resolved and seen in absorption against the continuum of the protostar. Several transitions of ammonia from 1.2 to 1.8 THz are also seen in absorption. These lines trace the low-density envelope of the protostar. Column densities and abundances are estimated for each hydride. We find that NH:NH_2:NH_3 $\approx$5:1:300. Dark clouds chemical models predict steady-state abundances of NH_2 and NH_3 in reasonable agreement with the present observations, whilst that of NH is underpredicted by more than one order of magnitude, even using updated kinetic rates. Additional modelling of the nitrogen gas-phase chemistry in dark-cloud conditions is necessary before having recourse to heterogen processes.

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The Dynamics of Dense Cores in the Perseus Molecular Cloud II: The Relationship Between Dense Cores and the Cloud

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We utilize the extensive datasets available for the Perseus molecular cloud to analyze the relationship between the kinematics of small-scale dense cores and the larger structures in which they are embedded. The kinematic measures presented here can be used in conjunction with those discussed in our previous work as strong observational constraints that numerical simulations (or analytic models) of star formation should match. We find that dense cores have small motions with respect to the ^{13}CO gas, about one third of the ^{13}CO velocity dispersion along the same line of sight. Within each extinction region, the core-to-core velocity dispersion is about half of the total (^{13}CO) velocity dispersion seen in the region. Large-scale velocity gradients account for roughly half of the total velocity dispersion in each region, similar to what is predicted from large-scale turbulent modes following a power spectrum of $P(k) \propto k^{-4}$.

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HST and Spitzer Observations of the HD 207129 Debris Ring

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A debris ring around the star HD 207129 (G0V; $d = 16.0$ pc) has been imaged in scattered visible light with the ACS coronagraph on the *Hubble Space Telescope* and in thermal emission using MIPS on the *Spitzer Space Telescope* at $\lambda = 70\ \mu$m (resolved) and 160 μm (unresolved). *Spitzer* IRS (λ = 7–35 μm) and MIPS (λ = 55–90 μm) spectrographs measured disk emission at $\lambda > 28\ \mu$m. In the HST image the disk appears as a ∼30 AU wide ring with a mean radius of ∼163 AU and is inclined by 60° from pole-on. At 70 μm it appears partially resolved and is elongated in the same direction and with nearly the same size as seen with HST in scattered light. At 0.6 μm the ring shows no significant brightness asymmetry, implying little or no forward scattering by its constituent dust. With a mean surface brightness of $V = 23.7$ mag arcsec^{-2}, it is the faintest disk imaged to date in scattered light.

We model the ring's infrared spectral energy distribution using a dust population fixed at the location where HST detects the scattered light. The observed SED is well-fit by this model, with no requirement for additional unseen debris zones. The firm constraint on the dust radial distance breaks the usual grain size-distance degeneracy that exists in modeling of spatially unresolved disks, and allows us to infer a minimum grain size of $\sim 2.8\mu$m and a dust size distribution power law spectral index of -3.9. An albedo of ∼5% is inferred from the integrated brightness of the ring in scattered light. The low albedo and isotropic scattering properties are inconsistent with Mie theory for astronomical silicates with the inferred grain size and show the need for further modeling using more complex grain shapes or compositions.

Brightness limits are also presented for six other main sequence stars with strong *Spitzer* excess around which HST detects no circumstellar nebulosity (HD 10472, HD 21997, HD 38206, HD 82943, HD 113556, and HD 138965).

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Circumventing the radiation pressure barrier in the formation of massive stars via disk accretion

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We present radiation hydrodynamics simulations of the collapse of massive pre-stellar cores. We treat frequency dependent radiative feedback from stellar evolution and accretion luminosity at a numerical resolution down to 1.27 AU. In the 2D approximation of axially symmetric simulations, it is possible for the first time to simulate the whole accretion phase (up to the end of the accretion disk epoch) for the forming massive star and to perform a broad scan of the parameter space. Our simulation series show evidently the necessity to incorporate the dust sublimation front to preserve the high shielding property of massive accretion disks. While confirming the upper mass limit of spherically symmetric accretion, our disk accretion models show a persistent high anisotropy of the corresponding thermal radiation field. This yields to the growth of the highest-mass stars ever formed in multi-dimensional radiation hydrodynamics simulations, far beyond the upper mass limit of spherical accretion. Non-axially symmetric effects are not necessary to sustain accretion. The radiation pressure launches a stable bipolar outflow, which grows in angle with time as presumed from observations. For an initial mass of the pre-stellar host core of 60, 120, 240, and 480 Msun the

masses of the final stars formed in our simulations add up to 28.2, 56.5, 92.6, and at least 137.2 Msun respectively.

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Lowering the Characteristic Mass of Cluster Stars by Magnetic Fields and Outflow Feedback

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Magnetic fields are generally expected to increase the characteristic mass of stars formed in stellar clusters, because they tend to increase the effective Jeans mass. We test this expectation using adaptive mesh refinement (AMR) magnetohydrodynamic simulations of cluster formation in turbulent magnetized clumps of molecular clouds, treating stars as accreting sink particles. We find that, contrary to the common expectation, a magnetic field of strength in the observed range decreases, rather than increases, the characteristic stellar mass. It (1) reduces the number of intermediate-mass stars that are formed through direct turbulent compression, because sub-regions of the clump with masses comparable to those of stars are typically magnetically subcritical and cannot be compressed directly into collapse, and (2) increases the number of low-mass stars that are produced from the fragmentation of dense filaments. The filaments result from mass accumulation along the field lines. In order to become magnetically supercritical and fragment, the filament must accumulate a large enough column density (proportional to the field strength), which yields a high volume density (and thus a small thermal Jeans mass) that is conducive to forming low-mass stars. We find, in addition, that the characteristic stellar mass is reduced further by outflow feedback. The conclusion is that both magnetic fields and outflow feedback are important in shaping the stellar initial mass function (IMF).

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Physical properties of dense cores in Orion B9

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Aims: We aim to determine the physical and chemical properties of the starless and protostellar cores in Orion B9 which represents a relatively quiescent star-forming region in Orion B.

Methods: We observed the NH_3 $(J, K) = (1, 1)$ and $(2, 2)$ inversion lines, and the $N_2H^+(3-2)$ rotational lines, with the Effelsberg 100-m and APEX telescopes, respectively, towards the submillimetre peak positions in Orion B9. These data are used in conjunction with our APEX/LABOCA 870 μm dust continuum data of the region.

Results: The gas kinetic temperature in the cores derived from the NH_3 data is between $\sim 9.4 - 13.9$ K. The non-thermal velocity dispersion is subsonic in most of the cores. The non-thermal linewidth in protostellar cores appears to increase with increasing bolometric luminosity. The core masses, $\sim 2 - 8$ $M_\odot$, are very likely drawn from the same parent distribution as the core masses in Orion B North. Based on the virial parameter analysis, starless cores in the region are likely to be gravitationally bound, and thus prestellar. Some of the cores have a lower radial velocity than the systemic velocity of the region, suggesting that they are members of the “low-velocity part” of Orion B. The observed core-separation distances deviate from the corresponding random-like model distributions. The distances between the nearest-neighbours are comparable to the thermal Jeans length. The fractional abundances of NH_3 and N_2H^+ in the cores are $\sim 1.5 - 9.8 \times 10^{-8}$ and $\sim 0.2 - 5.9 \times 10^{-10}$, respectively. The NH_3 abundance appears to decrease with increasing H_2 column and number densities. The NH_3/N_2H^+ column density ratio is larger in starless cores than in cores with embedded protostars.

Conclusions: The core population in Orion B9 is comparable in physical properties to those in nearby low-mass star-forming regions. The Orion B9 cores also seem to resemble cores found in isolation rather than those associated with clusters. Moreover, because the cores may not be randomly distributed within the region (contrary to that suggested in Paper I (Miettinen et al. 2009)), it is unclear if the origin of cores could be explained by turbulent fragmentation. On the other hand, many of the core properties conform with the picture of dynamic core evolution. The Orion B9 region has probably been influenced by the feedback from the nearby Ori OB 1b group, and the fragmentation of the parental cloud into cores could be caused by gravitational instability.

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Collisional formation of very massive stars in dense clusters

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We investigate the contraction of accreting protoclusters using an extension of n-body techniques that incorporates the accretional growth of stars from the gaseous reservoir in which they are embedded. Following on from Monte Carlo studies by Davis et al., we target our experiments toward populous clusters likely to experience collisions as a result of accretion-driven contraction. We verify that in less extreme star forming environments, similar to Orion, the stellar density is low enough that collisions are unimportant, but that conditions suitable for stellar collisions are much more easily satisfied in large-n clusters, i.e. n   30,000 (we argue, however, that the density of the Arches cluster is insufficient for us to expect stellar collisions to have occurred in the cluster's prior evolution). We find that the character of the collision process is not such that it is a route toward smoothly filling the top end of the mass spectrum. Instead, runaway growth of one or two extreme objects can occur within less than 1 Myr after accretion is shut off, resulting in a few objects with masses several times the maximum reached by accretion. The rapid formation of these objects is due to not just the post-formation dynamical evolution of the clusters, but an interplay of dynamics and the accretional growth of the stars. We find that accretion-driven cluster shrinkage results in a distribution of gas and stars that offsets the disruptive effect of gas expulsion, and we propose that the process can lead to massive binaries and early mass segregation in star clusters.

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The RMS Survey: The Bolometric Fluxes and Luminosity Distributions of Young Massive Stars

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Context: The Red MSX Source (RMS) survey is returning a large sample of massive young stellar objects (MYSOs) and ultra-compact (UC) H II regions using follow-up observations of colour-selected candidates from the MSX point source catalogue.
Aims: To obtain the bolometric fluxes and, using kinematic distance information, the luminosities for young RMS sources with far-infrared fluxes.
Methods: We use a model spectral energy distribution (SED) fitter to obtain the bolometric flux for our sources, given flux data from our work and the literature. The inputs to the model fitter were optimised by a series of investigations

designed to reveal the effect varying these inputs had on the resulting bolometric flux. Kinematic distances derived from molecular line observations were then used to calculate the luminosity of each source.
Results: Bolometric fluxes are obtained for 1173 young RMS sources, of which 1069 have uniquely constrained kinematic distances and good SED fits. A comparison of the bolometric fluxes obtained using SED fitting with trapezium rule integration and two component greybody fits was also undertaken, and showed that both produce considerable scatter compared to the method used here.
Conclusions: The bolometric flux results allowed us to obtain the luminosity distributions of YSOs and UCH II regions in the RMS sample, which we find to be different. We also find that there are few MYSOs with $L \geq 10^5 L_\odot$, despite finding many MYSOs with $10^4 L_\odot \geq L \geq 10^5 L_\odot$.

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Self-Consistent Analysis of OH-Zeeman Observations: Too Much Noise about Noise

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We had recently re-analyzed in a self-consistent way OH-Zeeman observations in four molecular-cloud envelopes and we had shown that, contrary to claims by Crutcher et al., there is no evidence that the mass-to-flux ratio decreases from the envelopes to the cores of these clouds. The key difference between our data analysis and the earlier one by Crutcher et al. is the relaxation of the overly restrictive assumption made by Crutcher et al, that the magnetic field strength is independent of position in each of the four envelopes. In a more recent paper, Crutcher et al. (1) claim that our analysis is not self-consistent, in that it misses a cosine factor, and (2) present new arguments to support their contention that the magnetic-field strength is indeed independent of position in each of the four envelopes. We show that the claim of the missing cosine factor is false, that the new arguments contain even more serious problems than the Crutcher et al. original data analysis, and we present new observational evidence, independent of the OH-Zeeman data, that suggests significant variations in the magnetic-field strength in the four cloud envelopes.

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The Star Formation Rate of Supersonic MHD Turbulence

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This work presents a new physical model of the star formation rate (SFR), verified with an unprecedented set of large numerical simulations of driven, supersonic, self-gravitating, magneto-hydrodynamic (MHD) turbulence, where collapsing cores are captured with accreting sink particles. The model depends on the relative importance of gravitational, turbulent, magnetic, and thermal energies, expressed through the virial parameter, $\alpha_{\rm vir}$, the rms sonic Mach number, $\mathcal{M}_{\rm S,0}$, and the ratio of mean gas pressure to mean magnetic pressure, β_0. The SFR is predicted to decrease with increasing $\alpha_{\rm vir}$ (stronger turbulence relative to gravity), to increase with increasing $\mathcal{M}_{\rm S,0}$ (for constant values of $\alpha_{\rm vir}$), and to depend weakly on β_0 for values typical of star forming regions ($\mathcal{M}_{\rm S,0} \approx$ 4-20 and $\beta_0 \approx$ 1-20). In the unrealistic limit of $\beta_0 \to \infty$, that is in the complete absence of a magnetic field, the SFR increases approximately by a factor of three, which shows the importance of magnetic fields in the star formation process, even when they are relatively weak (super-Alfvénic turbulence). In this non-magnetized limit, our definition of the critical density for star formation has the same dependence on $\alpha_{\rm vir}$, and almost the same dependence on $\mathcal{M}_{\rm S,0}$, as in the model of Krumholz and McKee, although our physical derivation does not rely on the concepts of local turbulent pressure and sonic scale. However, our model predicts a different dependence of the SFR on $\alpha_{\rm vir}$ and $\mathcal{M}_{\rm S,0}$ than the model of Krumholz and McKee. The star-formation simulations used to test the model result in an approximately constant

SFR, after an initial transient phase. Both the value of the SFR and its dependence on the virial parameter found in the simulations are shown to agree very well with the theoretical predictions. A physical model of the SFR is needed for a realistic implementation of the star formation feedback in simulations of galaxy formation, and to retrieve the correct morphological and chemical evolution of galaxies. The new star formation law derived in this paper is suitable for such applications.

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Spectral Energy Distributions of 6.7 GHz methanol masers

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The 6.7 GHz maser transition of methanol has been found exclusively towards massive star forming regions. A majority of the masers have been found to lack the presence of any associated radio continuum. This could be due to the maser emission originating prior to the formation of an H II region around the central star, or from the central object being too cool to produce a H II region. One way to distinguish between the two scenarios is to determine and model the spectral energy distributions (SEDs) of the masers. We observed a sample of 20 6.7 GHz methanol masers selected from the blind Arecibo survey, from centimeter to submillimeter wavelengths. We combined our observations with existing data from various Galactic plane surveys to determine SEDs from centimeter to near-infrared wavelengths. We find that 70% of the masers do not have any associated radio continuum, with the rest of the sources being associated with hypercompact and ultracompact H II regions. Modeling the SEDs shows them to be consistent with rapidly accreting massive stars, with accretion rates well above 10^{-3} $M_\odot$ yr^{-1}. The upper limits on the radio continuum are also consistent with any ionized region being confined close to the stellar surface. This confirms the paradigm of 6.7 GHz methanol masers being signposts of early phases of massive star formation, mostly prior to the formation of a hypercompact H II region.

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Extended emission of D_2H^+ in a prestellar core

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Context: In the last years, the H_2D^+ and D_2H^+ molecules have gained great attention as probes of cold and depleted dense molecular cloud cores. These ions are at the basis of molecular deuterium fractionation, a common characteristic observed in star forming regions. H_2D^+ is now routinely observed, but the search for its isotopologue D_2H^+ is still difficult because of the high frequency of its ground para transition (692 GHz).
Aims: We have observed molecular transitions of H_2D^+ and D_2H^+ in a cold prestellar core to characterize the roots of deuterium chemistry.
Methods: Thanks to the sensitive multi-pixel CHAMP$^+$ receiver on the APEX telescope where the required excellent weather conditions are met, we not only successfully detect D_2H^+ in the H-MM1 prestellar core located in the L1688 cloud, but also obtain information on the spatial extent of its emission. We also detect H_2D^+ at 372 GHz in the same source. We analyse these detections using a non-LTE radiative transfer code and a state-of-the-art spin-dependent chemical model.
Results: This observation is the first secure detection of D_2H^+ in space. The emission is moreover extended over several pixels of the CHAMP$^+$ array, i.e. on a scale of at least 40″, corresponding to $\sim$4800 AU. We derive column densities on the order of $10^{12}-10^{13}\,cm^{-2}$ for both molecules in the LTE approximation depending on the assumed

temperature, and up to two orders of magnitude higher based on a non-LTE analysis.
Conclusions: Our modeling suggests that the level of CO depletion must be extremely high (>10, and even >100 if the temperature of the core is around 10 K) at the core center, in contradiction with CO depletion levels directly measured in other cores. Observation of the H_2D^+ spatial distribution and direct measurement of the CO depletion in H-MM1 will be essential to confirm if present chemical models investigating the basis of deuterium fractionation of molecules need to be revised.

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A statistical study of the mass and density structure of Infrared Dark Clouds

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How and when the mass distribution of stars in the Galaxy is set is one of the main issues of modern astronomy. Here we present a statistical study of mass and density distributions of infrared dark clouds (IRDCs) and fragments within them. These regions are pristine molecular gas structures and progenitors of stars and so provide insights into the initial conditions of star formation. This study makes use of a IRDC catalogue (Peretto & Fuller 2009), the largest sample of IRDC column density maps to date, containing a total of ∼11,000 IRDCs with column densities exceeding $N_{H_2} = 1 \times 10^{22}$ cm^{-2} and over 50,000 single peaked IRDC fragments. The large number of objects constitutes an important strength of this study, allowing detailed analysis of the completeness of the sample and so statistically robust conclusions. Using a statistical approach to assigning distances to clouds, the mass and density distributions of the clouds and the fragments within them are constructed. The mass distributions show a steepening of the slope when switching from IRDCs to fragments, in agreement with previous results of similar structures. IRDCs and fragments are divided into unbound/bound objects by assuming Larson's relation and calculating their virial parameter. IRDCs are mostly gravitationally bound, while a significant fraction of the fragments are not. The density distribution of gravitationally unbound fragments shows a steep characteristic slope such as $\Delta N/\Delta \log(n) \propto n^{-4.0\pm0.5}$, rather independent of the range of fragment mass. However, the incompleteness limit at a number density of $\sim 10^3$ cm^{-3} does not allow us to exclude a potential lognormal density distribution. In contrast, gravitationally bound fragments show a characteristic density peak at $n \simeq 10^4$ cm^{-3} but the shape of the density distributions changes with the range of fragment masses. An explanation for this could be differential dynamical evolution of the fragment density with respect to their mass as more massive fragments contract more rapidly. The IRDC properties reported here provide a representative view of the density and mass structure of dense molecular clouds before and during the earliest stages of star formation. These should serve as constraints on any theoretical or numerical model to identify the physical processes involved in the formation and evolution of structure in molecular clouds.

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Star formation in the outer Galaxy: membership and fundamental parameters of the young open cluster NGC 1893

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Different environmental conditions can play a crucial role in determining final products of the star formation process and in this context, less favorable activities of star formation are expected in the external regions of our Galaxy. We studied the properties of the young open cluster NGC 1893 located about 12 Kpc from the galactic center, to

investigate how different physical conditions can affect the process of star formation. By adopting a multiwavelength approach, we compiled a catalog extending from X-rays to NIR data to derive the cluster membership. In addition, optical and NIR photometric properties are used to evaluate the cluster parameters. We find 415 diskless candidate members plus 1061 young stellar objects with a circumstellar disk or class II candidate members, 125 of which are also H_α emitters. Considering the diskless candidate members, we find that the cluster distance is 3.6±0.2 kpc and the mean interstellar reddening is E(B-V)=0.6±0.1 with evidence of differential reddening in the whole surveyed region. NGC 1893 contains a conspicuous population of pre-main sequence stars together with the well studied main sequence cluster population; we found a disk fraction of about 70% similar to that found in clusters of similar age in the solar neighbour and then, despite expected unfavorable conditions f or star formation, we conclude that very rich young clusters can form also in the outer regions of our Galaxy.

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Herschel observations of extra-ordinary sources: Detecting spiral arm clouds by CH absorption lines

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We have observed CH absorption lines ($J = 3/2, N = 1 \leftarrow J = 1/2, N = 1$) against the continuum source Sgr B2(M) using the *Herschel*/HIFI instrument. With the high spectral resolution and wide velocity coverage provided by HIFI, 31 CH absorption features with different radial velocities and line widths are detected and identified. The narrower line width and lower column density clouds show 'spiral arm' cloud characteristics, while the absorption component with the broadest line width and highest column density corresponds to the gas from the Sgr B2 envelope. The observations show that each 'spiral arm' harbors multiple velocity components, indicating that the clouds are not uniform and that they have internal structure. This line-of-sight through almost the entire Galaxy offers unique possibilities to study the basic chemistry of simple molecules in diffuse clouds, as a variety of different cloud classes are sampled simultaneously. We find that the linear relationship between CH and H_2 column densities found at lower A_V by UV observations does not continue into the range of higher visual extinction. There, the curve flattens, which probably means that CH is depleted in the denser cores of these clouds.

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First Results From VLT NACO Apodizing Phase Plate: 4-micron Images of the Exoplanet beta Pictoris b

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Direct imaging of exoplanets requires both high contrast and high spatial resolution. Here, we present the first scientific results obtained with the newly commissioned Apodizing Phase Plate coronagraph (APP) on VLT/NACO. We detected the exoplanet β Pictoris b in the narrow band filter centered at 4.05 μm (NB4.05). The position angle ($209.13° \pm 2.12°$) and the projected separation to its host star ($0.''354 \pm 0''.012$, i.e., 6.8 ± 0.2 AU at a distance of 19.3 pc) are in good agreement with the recently presented data from Lagrange et al. (2010). Comparing the observed NB4.05 magnitude of 11.20 ± 0.23 mag to theoretical atmospheric models we find a best fit with a 7–10 $M_{\rm Jupiter}$ object for an age of 12 Myr, again in agreement with previous estimates. Combining our results with published L' photometry we can compare the planet's [L' − NB4.05] color to that of cool field dwarfs of higher surface gravity suggesting an effective temperature of ∼1700 K. The best fit theoretical model predicts an effective temperature of ∼1470 K, but this difference is not significant given our photometric uncertainties. Our results demonstrate the potential of NACO/APP for future planet searches and provides independent confirmation as well as complementary data for β Pic b.

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IRAS 22198+6336: Discovery of an Intermediate-Mass Hot Core

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We present new Submillimeter Array and Plateau de Bure Interferometer observations of the intermediate-mass object IRAS 22198+6336 in the millimeter continuum and in several molecular line transitions. The millimeter continuum emission reveals a strong and compact source with a mass of $\sim 5\ M_\odot$ and with properties of Class 0 objects. CO emission shows an outflow with a quadrupolar morphology centered on the position of the dust condensation. The CO outflow emission seems to come from two distinct outflows, one of them associated with SiO outflow emission. A large set of molecular lines has been detected toward a compact dense core clearly coincident with the compact millimeter source, and showing a velocity gradient perpendicular to the outflow traced by CO and SiO. The chemically rich spectrum and the rotational temperatures derived from CH_3CN and CH_3OH (100–150 K) indicate that IRAS 22198+6336 is harboring one of the few intermediate-mass hot cores known at present.

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C_{60} in Reflection Nebulae

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The fullerene C_{60} has four infrared-active vibrational transitions at 7.0, 8.5, 17.4 and 18.9 μm. We have previously observed emission features at 17.4 and 18.9 μm in the reflection nebula NGC 7023 and demonstrated spatial correlations suggestive of a common origin. We now confirm our earlier identification of these features with C_{60} by detecting a third emission feature at 7.04 $\pm$ 0.05 μm in NGC 7023. We also report the detection of these three C_{60} features in the reflection nebula NGC 2023. Our spectroscopic mapping of NGC 7023 shows that the 18.9 μm C_{60} feature peaks on the central star and that the 16.4 μm emission feature due to polycyclic aromatic hydrocarbons peaks between the star and a nearby photodissociation front. The observed features in NGC 7023 are consistent with emission from UV-excited gas-phase C_{60}. We find that 0.1–0.6% of interstellar carbon is in C_{60}; this abundance is consistent with those from previous upper limits and possible fullerene detections in the interstellar medium. This is the first firm detection of neutral C_{60} in the interstellar medium.

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Chandra Reveals Variable Multi-Component X-ray Emission from FU Orionis

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FU Orionis is the prototype of a class of eruptive young stars ("FUors") characterized by strong optical outbursts. We recently completed an exploratory survey of FUors using *XMM-Newton* to determine their X-ray properties, about which little was previously known. The prototype FU Ori and V1735 Cyg were detected. The X-ray spectrum of FU Ori was found to be unusual, consisting of a cool moderately-absorbed component plus a hotter component viewed through an absorption column density that is an order of magnitude higher. We present here a sensitive (99 ks) follow-up X-ray observation of FU Ori obtained at higher angular resolution with *Chandra* ACIS-S. The unusual multi-component spectrum is confirmed. The hot component is centered on FU Ori and dominates the emission above 2 keV. It is variable (a signature of magnetic activity) and is probably coronal emission originating close to FU Ori's surface viewed through cool gas in FU Ori's strong wind or accretion stream. In contrast, the X-ray centroid of the soft emission below 2 keV is offset 0.″20 to the southeast of FU Ori, toward the near-IR companion (FU Ori S). This offset amounts to slightly less than half the separation between the two stars. The most likely explanation for the offset is that the companion contributes significantly to the softer X-ray emission below 2 keV (and weakly above 2 keV). The superimposed X-ray contributions from FU Ori and the companion resolve the paradox posed by *XMM-Newton* of an apparently single X-ray source viewed through two different absorption columns.

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A molecular survey of outflow gas: velocity-dependent shock chemistry and the peculiar composition of the EHV gas

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Context. Bipolar outflows from Class 0 protostars often present two components in their CO spectra that have

different kinematic behaviors: a smooth outflow wing and a discrete, extremely high-velocity (EHV) peak.
Aims. To better understand the origin of these two outflow components, we have studied and compared their molecular composition.
Methods. We carried out a molecular survey of the outflows powered by L1448-mm and IRAS 04166+2706, two sources with prominent wing and EHV components. For each source, we observed a number of molecular lines towards the brightest outflow position and used them to determine column densities for 12 different molecular species.
Results. The molecular composition of the two outflows is very similar. It presents systematic changes with velocity that we analyze by dividing the outflow in three chemical regimes, two of them associated with the wing component and the other the EHV gas. The analysis of the two wing regimes shows that species like H_2CO and CH_3OH favor the low-velocity gas, while SiO and HCN are more abundant in the fastest gas. This fastest wing gas presents strong similarities with the composition of the "chemically active" L1157 outflow (whose abundances we re-evaluate in an appendix). We find that the EHV regime is relatively rich in O-bearing species compared to the wing regime. The EHV gas is not only detected in CO and SiO (already reported elsewhere), butalso in SO, CH_3OH, and H_2CO (newly reported here), with a tentative detection in HCO^+. At the same time, the EHV regime is relatively poor in C-bearing molecules like CS and HCN, for which we only obtain weak detections or upper limits despite deep integrations. We suggest that this difference in composition arises from a lower C/O ratio in the EHV gas.
Conclusions. The different chemical compositions of the wing and EHV regimes suggest that these two outflow components have different physical origins. The wing component is better explained by shocked ambient gas, although none of the existing shock models explains all observed features. We hypothesize that the peculiar composition of the EHV gas reflects its origin as a dense wind from the protostar or its surrounding disk.

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Embedded protostellar disks around (sub-)solar protostars. I. Disk structure and evolution

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We perform a comparative numerical hydrodynamics study of embedded protostellar disks formed as a result of the gravitational collapse of cloud cores of distinct mass ($M_{\rm cl}$=0.2–1.7 $M_\odot$) and ratio of rotational to gravitational energy (β=0.0028–0.023). An increase in $M_{\rm cl}$ and/or β leads to the formation of protostellar disks that are more susceptible to gravitational instability. Disk fragmentation occurs in most models but its effect is often limited to the very early stage, with the fragments being either dispersed or driven onto the forming star during tens of orbital periods. Only cloud cores with high enough $M_{\rm cl}$ or β may eventually form wide-separation binary/multiple systems with low mass ratios and brown dwarf or sub-solar mass companions. It is feasible that such systems may eventually break up, giving birth to rogue brown dwarfs. Protostellar disks of *equal* age formed from cloud cores of greater mass (but equal β) are generally denser, hotter, larger, and more massive. On the other hand, protostellar disks formed from cloud cores of higher β (but equal $M_{\rm cl}$) are generally thinner and colder but larger and more massive. In all models, the difference between the irradiation temperature and midplane temperature $\triangle T$ is small, except for the innermost regions of young disks, dense fragments, and disk's outer edge where $\triangle T$ is negative and may reach a factor of two or even more. Gravitationally unstable, embedded disks show radial pulsations, the amplitude of which increases along the line of increasing $M_{\rm cl}$ and β but tends to diminish as the envelope clears. We find that single stars with a disk-to-star mass ratio of order unity can be formed only from high-β cloud cores, but such massive disks are unstable and quickly fragment into binary/multiple systems. A substantial fraction of an embedded disk, especially its inner regions, spiral arms and dense clumps, may be optically thick, leading potentially to observational underestimates of disk masses in the embedded phase of star formation.

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Chemical Processes in Protoplanetary Disks

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We have developed a high resolution combined physical and chemical model of a protoplanetary disk surrounding a typical T Tauri star. Our aims were to use our model to calculate the chemical structure of disks on small scales (sub-milli-arcsecond in the inner disk for objects at the distance of Taurus, $\sim$ 140 pc) to investigate the various chemical processes thought to be important in disks and to determine potential molecular tracers of each process. Our gas-phase network was extracted from the UMIST Database for Astrochemistry to which we added gas-grain interactions including freeze out and thermal and non-thermal desorption (cosmic-ray induced desorption, photodesorption and X-ray desorption) and a grain-surface network. We find that cosmic-ray induced desorption has the least effect on our disk chemical structure while photodesorption has a significant effect, enhancing the abundances of most gas-phase molecules throughout the disk and affecting the abundances and distribution of HCN, CN and CS, in particular. In the outer disk, we also see enhancements in the abundances of H_2O and CO_2. X-ray desorption is a potentially powerful mechanism in disks, acting to homogenise the fractional abundances of gas-phase species across the depth and increasing the column densities of most molecules although there remain significant uncertainties in the rates adopted for this process. The addition of grain-surface chemistry enhances the fractional abundances of several small complex organic molecules including CH_3OH, $HCOOCH_3$ and CH_3OCH_3 to potentially observable values (i.e. a fractional abundance of $\gtrsim 10^{-11}$).

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http://star.pst.qub.ac.uk/~cw/Papers/wals2505_apj_format.pdf

Ammonia and CO Observations Toward Low-luminosity 6.7 GHz Methanol Masers

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To investigate whether distinctions exist between low- and high-luminosity Class II 6.7 GHz methanol masers, we have undertaken multi-line mapping observations of various molecular lines, including the NH_3 (1,1), (2,2), (3,3), (4,4), and ^{12}CO (1-0) transitions, toward a sample of nine low-luminosity 6.7 GHz masers and ^{12}CO (1-0) observations toward a sample of eight high-luminosity 6.7 GHz masers, for which we already had NH3 spectral line data. Emission in the NH_3 (1,1), (2,2), and (3,3) transitions was detected in eight out of nine low-luminosity maser sources, in which 14 cores were identified. We derive densities, column densities, temperatures, core sizes, and masses of both low- and high-luminosity maser regions. A comparative analysis of the physical quantities reveals marked distinctions between the low-luminosity and high-luminosity groups: in general, cores associated with high-luminosity 6.7 GHz masers are larger and more massive than those traced by low-luminosity 6.7 GHz masers; regions traced by the high-luminosity masers have larger column densities but lower densities than those of the low-luminosity maser regions. Further, strong correlations between 6.7 GHz maser luminosity and NH_3 (1,1) and (2,2) line widths are found, indicating that internal motions in high-luminosity maser regions are more energetic than those in low-luminosity maser regions. A ^{12}CO (1-0) outflow analysis also shows distinctions in that outflows associated with high-luminosity masers have wider line wings and larger sizes than those associated with low-luminosity masers.

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Physical Processes in Magnetically Driven Flares on the Sun, Stars, and Young Stellar Objects

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The first flare on the Sun was observed exactly 150 years ago. During most of the long history, only secondary effects have been noticed, so flares remained a riddle. Now the primary flare products, high-energy electrons and ions, can be spatially resolved in hard X-rays (HXRs) and gamma rays on the Sun. Soft X-rays (SXRs) are observed from most stars, including young stellar objects. Structure and bulk motions of the corona are imaged on the Sun in high temperature lines and are inferred from line shifts in stellar coronae. Magnetic reconnection is the trigger for reorganization of the magnetic field into a lower energy configuration. A large fraction of the energy is converted into nonthermal particles that transport the energy to higher density gas, heating it to SXR-emitting temperatures. Flares on young stars are several orders of magnitude more luminous and more frequent; they significantly ionize protoplanetary disks and planetary ionospheres.

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http://www.annualreviews.org/eprint/dEJCtmKMZjhnf6H8jPWq/full/10.1146/annurev-astro-082708-101757

The Origin and Inner Workings of Star-Forming Cores

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Ph.D dissertation directed by: Alyssa A Goodman

Ph.D degree awarded: June 2010

Low-mass stars are formed in molecular clouds, but only in the densest and coldest regions within molecular clouds called "Dense Cores." This thesis presents a wide variety of observations, from centimeter to millimeter wavelengths observed with both single dish and interferometers, that allow us to study the star formation process in the Perseus molecular cloud complex starting from the large-scale structure using low-density gas tracers and then zooming into the smaller scales where dense cores form stars. Here we address the following open questions in star formation: (1) do changes in the environment affect chemical abundances in a molecular cloud?; (2) what is the mass function of substructures in molecular clouds?; (3) how are dense cores connected with their environment?; (4) what are the earliest stage of star formation?. We use large-scale molecular line and extinction maps to show that within a single molecular cloud large variations in the molecular abundance are found, we also study the reliability and limitations of ^{12}CO, ^{13}CO, and $C^{18}O$(1–0) lines to trace the total column density. We also study the robustness of sub-structures in molecular clouds and its associated mass function, and we show that the results are affected by the molecular cloud hierarchical structure. Our study of dense cores presents, for the first time in a single tracer, observations of a sharp transition between gas with supersonic and subsonic turbulence using large scale NH_3 maps observed with the GBT towards several regions, this result provides a strong test on theories of star formation. We present a "First Hydrostatic Core" candidate (an object only found in numerical calculations formed in the earliest stage of star formations) inside a starless (Spitzer) dense core, which is identified using dust continuum and molecular line interferometric observations (using SMA and CARMA) and it is also modeled using a radiative transfer code to confirm the presence of a central young object.

The Chemical Structure of Protoplanetary Disks

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Ph.D dissertation directed by: Professor T. J. Millar

Ph.D degree awarded: July 2010

We have developed a high-resolution computational chemical model of a protoplanetary disk surrounding a T Tauri star to investigate the importance of different chemical processes in disks and to make predictions for observations at the expected resolution of the Atacama Large Millimeter Array (ALMA).

We used a comprehensive gas-phase network extracted from the UMIST Database for Astrochemistry to which we added the freeze out and desorption of species onto, and from, dust grains. We considered the chemical effects of desorption mechanisms including thermal desorption, cosmic-ray induced desorption, photodesorption and X-ray desorption. We studied the impact of the varying UV radiation spectrum and X-ray energy spectrum on the photochemistry and X-ray chemistry. We added a large grain-surface reaction set to explore the effects on the synthesis of complex organic molecules. Assuming local thermodynamic equilibrium, we calculated the radiative transfer in the disk to produce molecular rotational line profiles and integrated intensities for comparison with existing observations. We generated synthetic maps of molecular line emission for different disk inclinations and used our data as input for the GILDAS ALMA simulator to investigate the optimum ALMA observational parameters for the resolution of the chemical and physical structure of protoplanetary disks.

We find the chemical structure closely traces the physical structure with chemical stratification in both the radial and vertical directions of the disk. Cosmic-ray induced desorption shows least effect on the chemistry with both photodesorption and X-ray desorption releasing molecules from the dust grains and enhancing the gas-phase chemistry. X-ray desorption, in particular, has an effect in the midplane of the disk. The calculation of spectrum dependent photo-rates and X-ray ionisation rates slightly lowers the ionisation of species and dissociation of molecules leading to an increase in molecular abundances, particularly in the inner disk region. Grain-surface chemistry enhances the abundances of several small complex organic molecules to within potentially detectable limits.

Our calculated line profiles and intensities compare well with those observed in the disk of TW Hya, however, agreement worsens with increasing disk inclination highlighting the limitations of the truncation of our model at 305 AU. We find that ALMA will have sufficient resolution and sensitivity to trace the chemical and physical structure of disks on small scales for molecular transitions within ALMA's frequency ranges.

http://star.pst.qub.ac.uk/∼cw/Thesis/Catherine_Walsh_Thesis.pdf

Johannes Kepler Postdoctoral Program in Astrophysics University of Vienna

The University of Vienna announces the opening of its newly established Johannes Kepler Postdoctoral Program in Astrophysics. Johannes Kepler positions will be awarded to outstanding postdoctoral scientists demonstrating a high research profile in observational, numerical, or theoretical astrophysics in areas covered at the Department of Astronomy in Vienna. Kepler postdocs will carry out their independent research programs, but are strongly encouraged to engage in collaborations within the Department. A modest level of teaching is expected.

The present announcement is for a position dedicated preferentially to the area of **galactic star formation and pre-main sequence stars**, including research on protoplanetary disks and planet formation, but excellent candidates in other fields of the Department's research will also be considered. Johannes Kepler positions are awarded for four years. Funds are made available to support travel expenses and conference participation.

The Kepler postdoc will have access to all observatories of ESO and ESA; for numerical work, two in-house clusters and, for high-performance computing, the Vienna Scientific Cluster will be accessible. The institute provides a lively research environment including approx. 70 staff members, postdocs, and PhD students. There are many opportunities to interact within ongoing or planned instrument projects for example related to Plato, Spica, or ESO observatories.

Applications include a CV, a publication list, a summary of past research (max 2 pages) and an outline of the proposed research program for the duration of the employment (max. 4 pages). These documents must be submitted electronically as a PDF file via http://jobcenter.univie.ac.at/en/applications/ or to Prof. Manuel Güdel, manuel.guedel *at* univie.ac.at.

Review starts 10 October 2010 but applications submitted thereafter will be fully considered until the post is filled. Applicants should arrange for three letters of reference sent by the referees directly to the same address. Future announcements will be made upon availability of positions. Female candidates are especially encouraged to apply.

The Johannes Kepler Postdoctoral Program in Astrophysics at the University of Vienna is managed by the board of professors at the Department of Astronomy. For inquiries, contact Prof. M. Güdel (manuel.guedel *at* univie.ac.at).

Infrared Instrumentation/Exoplanet Science Institute for Astronomy, ETH Zurich

The Institute for Astronomy at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) is expanding its existing instrumentation laboratory into the infrared with a scientific focus on the search for, and characterization of extra-solar planets. Current projects include development of high contrast imaging systems and integral field spectrographs from 1-5 microns for existing large telescopes, as well as the next generation ELTs. Our group is involved in the SPHERE project (a second-generation instrument for the VLT), the EPICS project (a proposed high-contrast instrument for the 42 meter E-ELT), and anticipates involvement in the METIS project (a proposed mid-IR instrument for the E-ELT), as well as the LMIRCam project (under construction for the LBT), among others. We are also interested in developing novel algorithms to optimize exoplanet detection.

International applications are invited for positions ranging from Postdoctoral Fellow to Assistant Scientist capable of directing the lab. Salary will be commensurate with experience (CHF/US$ 83'700-120'000) with junior appointments for a minimum of two years, and up to six+ years for senior candidates. Successful applicants will have the opportunity to work with students and access to the resources of the Star and Planet Formation Research Group. Switzerland is a member of ESO and ESA, and successful applicants will have full access to their facilities, as well as data from ongoing programs utilizing the Spitzer Space Telescope, HST, Herschel, the VLT, and other telescopes.

Applications should consist of a CV, past research and instrumentation experience, and proposed future activities (combined length not to exceed 12 pages). A separate publication list should be attached. These materials (as a single pdf file) as well as three letters of reference (directly from the referees) should be sent via email to chiesinm *at* phys.ethz.ch. The ETH will provide benefits for maternity leave, retirement, accident insurance, and relocation costs. Weblink: http://www.pa.ethz.ch/. More information concerning our group and the Institute for Astronomy can be found at: http://www.astro.phys.ethz.ch/. Email Inquiries: mmeyer *at* phys.ethz.ch or schmid *at* astro.phys.ethz.ch. The closing date for receipt of applications: 12/15/2010

PhD position
Photodissociation and excitation of molecules in protoplanetary disks

A 4-year PhD (AIO) position is available to study the photodissociation and excitation of astrophysically relevant small molecules in protoplanetary disks. The project is part of an interdisciplinary collaboration between astronomers and chemists in the context of the Dutch Astrochemistry Network. Determining the physical and chemical structure of planet-forming disks is a major goal of new large observational facilities such as the Atacama Large Millimeter Array (ALMA), the James Webb Space Telescope (JWST) and the European Extremely Large Telescope (E-ELT). Photodissociation of molecules in the upper layers of the disk is a key process in setting their chemical structure. The aim of the project is to investigate the chemical processes and integrate the resulting rates and product branching ratios into protoplanetary disk models. The model results will be compared with existing and future observational data. The initial focus will be on the N_2 molecule, a key species in the nitrogen chemistry. Also, the excitation of molecules like CO and OH will be studied using newly determined collisional rate coefficients.

Applications should include a curriculum vitae (with a list of grades for exams), a brief statement of research experience, and the names of at least two people who can serve as a reference. Selection of candidates will start on October 1 2010 and will continue until the position is filled. The positions are open to students of all nationalities with the equivalent of a Masters degree in astronomy, physics or chemistry. The starting date for the positions can be anytime up to March 2011. Please submit applications through:

http://jobs.strw.leidenuniv.nl/2010/dishoeckAIO/

See www.strw.leidenuniv.nl/∼ewine

www.nwo.nl/astrochemistry

www.nova-astronomy.nl

for further information about Leiden Observatory, the Dutch PhD program and the Dutch Astrochemistry Network. The research is carried out in the framework of the Netherlands Research School for Astronomy (NOVA).

Gordon Research Conference Origins of Solar Systems

The 2011 Gordon Research Conference on Origins of Solar Systems will take place at Mt. Holyoke College in South Hadley, MA 17-22 July. This unique interdisciplinary meeting includes astronomers and astrophysicists interested in star and planet formation, planetary scientists and cosmochemists interested in the early history, structure, and evolution of the Solar System, as well as scientists in related disciplines. By bringing together this mix of expertise the conference attempts to address fundamental questions that are not tractable within the confines of just one discipline. Our goal is to understand whether planetary systems like our own, and the potential for habitability that they represent are the exception or the rule in the Milky Way galaxy.

The focus of the 2011 meeting (the 11th since this series began twenty years ago) will be "Composition of Forming Planets: A Tool to Understand Processes". Topics covered will include: 1) the initial conditions for planet formation in circumstellar disks, including estimates of solar nebula composition from the Genesis mission; 2) the evolution of the physical structure of the gas and dust from which planets form; 3) progress in our theoretical understanding of the major physical processes that control planet formation; 4) the interplay between disk dynamics and disk chemistry in determining the composition of forming planets including new results from the Herschel Space Telescope; 5) meteoritic constraints on the physical and chemical conditions in the solar nebula; 6) the role of giant impacts in the structure and evolution of forming planets; 7) satellites and rings of giant planets as mini-laboratories to study the process of planet formation; 8) current census of extra-solar planets including new results from the Kepler and COROT missions as well as other facilities; 9) the essential chemical conditions for life and whether those are readily obtained through our current understanding of planet formation; and many other topics.

The conference will continue the usual format of invited lectures, extended discussion, and poster sessions. The meeting provides an excellent opportunity for young researchers to present their latest research results and to participate in the dynamic informal conversations that are typical of a Gordon Conference. We encourage young scientists, including graduate students and postdoctoral fellows, to attend. Special efforts will be made to promote interactions between invited speakers and junior participants and we expect to provide some financial support to facilitate the latter's participation.

More information can be found at http://www.grc.org.

Workshop: Star formation under Extreme Conditions: the Galactic Center

Besancon (France), 6-9 december 2010

We are organising here in Besancon (France) a workshop about Star Formation in the Galactic Center between 6-9 December. For more information you can consult this webpage
http://www.obs-besancon.fr/AtelierEtoilesJeunes/2010/index.php

Moving ... ??

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