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Abstracts of recently accepted papers

The 2008 Extreme Outburst of the Young Eruptive Variable Star EX Lupi

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In early 2008, the young low-mass star EX Lupi, the prototype of the EXor class of eruptive variables, optically brightened by over five magnitudes for a period of 7 months. The previous time a change of such amplitude had been observed in EX Lup was over 50 years ago. In this Letter we present new optical and near-IR high resolution spectroscopy of EX Lup during the 2008 outburst. We investigate the physical characteristics of the outburst both soon after it began and some four months later, and consider the energetics and kinematics observed. Emission line strengths, widths, and profiles changed significantly between the two observations. Also, modeling of the 2.2935 μm CO overtone bandhead emission suggests that an inner gap in the circumstellar gas disk around the star may be present and it is from the inner edge of the gas disk that the CO overtone emission probably arises. We derive a mass accretion luminosity and rate during the extreme outburst of $\sim$2$\pm$0.5 $L_\odot$ and $\sim$2$\pm$0.5 $\times$ 10^{-7} $M_\odot$ yr^{-1}, respectively, which suggests that this outburst was indeed one of the strongest witnessed in EX Lup, yet not as strong as those observed in FU Orionis stars.

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http://arxiv.org/abs/1007.4178

An Infrared through Radio Study of the Properties and Evolution of IRDC Clumps

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We examine the physical properties and evolutionary stages of a sample of 17 clumps within 8 Infrared Dark Clouds (IRDCs) by combining existing infrared, millimeter, and radio data with new Bolocam Galactic Plane Survey (BGPS) 1.1 mm data, VLA radio continuum data, and HHT dense gas (HCO^+ and N_2H^+) spectroscopic data. We combine literature studies of star formation tracers and dust temperatures within IRDCs with our search for ultra-compact (UC) H II regions to discuss a possible evolutionary sequence for IRDC clumps. In addition, we perform an analysis of mass tracers in IRDCs and find that 8 μm extinction masses and 1.1 mm Bolocam Galactic Plane Survey (BGPS) masses are complementary mass tracers in IRDCs except for the most active clumps (notably those containing UCH II regions), for which both mass tracers suffer biases. We find that the measured virial masses in IRDC clumps are uniformly higher than the measured dust continuum masses on the scale of $\sim$ 1 pc. We use ^{13}CO, HCO^+, and N_2H^+ to study the molecular gas properties of IRDCs and do not see any evidence of chemical differentiation between hot and cold clumps on the scale of ~ 1 pc. However, both HCO^+ and N_2H^+ are brighter in active clumps, due to an increase in temperature and/or density. We report the identification of four UCH II regions embedded within IRDC clumps and find that UCH II regions are associated with bright ($\gtrsim 1$ Jy) 24 μm point sources, and that the brightest UCH II regions are associated with "diffuse red clumps" (an extended enhancement at 8 μm). The broad stages of the discussed evolutionary sequence (from a quiescent clump to an embedded H II region) are supported by literature dust temperature estimates; however, no sequential nature can be inferred between the individual star formation tracers.

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LIME - a flexible, non-LTE line excitation and radiation transfer method for millimeter and far-infrared wavelengths

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We present a new code for solving the molecular and atomic excitation and radiation transfer problem in a molecular gas and predicting emergent spectra. This code works in arbitrary three dimensional geometry using unstructured Delaunay latices for the transport of photons. Various physical models can be used as input, ranging from analytical descriptions over tabulated models to SPH simulations. To generate the Delaunay grid we sample the input model randomly, but weigh the sample probability with the molecular density and other parameters, and thereby we obtain an average grid point separation that scales with the local opacity. Our code does photon very efficiently so that the slow convergence of opaque models becomes traceable. When convergence between the level populations, the radiation field, and the point separation has been obtained, the grid is ray-traced to produced images that can readily be compared to observations. Because of the high dynamic range in scales that can be resolved using this type of grid, our code is particularly well suited for modeling of ALMA data. Our code can furthermore deal with overlapping lines of multiple molecular and atomic species.

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http://arxiv.org/abs/1008.1492

Multidimensional Chemical Modeling. III. Abundance and excitation of diatomic hydrides

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The Herschel Space Observatory opens the sky for observations in the far infrared at high spectral and spatial resolution. A particular class of molecules will be directly observable; light diatomic hydrides and their ions (CH, OH, SH, NH, CH^+, OH^+, SH^+, NH^+). These simple constituents are important both for the chemical evolution of the region and as tracers of high-energy radiation. If outflows of a forming star erode cavities in the envelope, protostellar far UV (FUV; $6 < E_\gamma < 13.6$ eV) radiation may escape through such low-density regions. Depending on the shape of the cavity, the FUV radiation then irradiates the quiescent envelope in the walls along the outflow. The chemical composition in these outflow walls is altered by photoreactions and heating via FUV photons in a manner similar to photo dominated regions (PDRs).
In this work, we study the effect of cavity shapes, outflow density, and of a disk with the two-dimensional chemical model of a high-mass young stellar object introduced in the second paper in this series. The model has been extended with a self-consistent calculation of the dust temperature and a multi-zone escape probability method for the calculation of the molecular excitation and the prediction of line fluxes.
We find that the shape of the cavity is particularly important in the innermost part of the envelope, where the dust temperatures are high enough ($\gtrsim$100 K) for water ice to evaporate. If the cavity shape allows FUV radiation to penetrate this hot-core region, the abundance of FUV destroyed species (e.g. water) is decreased. On larger scales,

the shape of the cavity is less important for the chemistry in the outflow wall. In particular, diatomic hydrides and their ions CH^+, OH^+ and NH^+ are enhanced by many orders of magnitude in the outflow walls due to the combination of high gas temperatures and rapid photodissociation of more saturated species. The enhancement of these diatomic hydrides is sufficient for a detection using the HIFI and PACS instruments onboard Herschel. The effect of X-ray ionization on the chemistry is found to be small, due to the much larger luminosity in FUV bands compared to X-rays.

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http://arxiv.org/abs/1007.3261

Herschel-HIFI detections of hydrides towards AFGL 2591 (Envelope emission versus tenuous cloud absorption)

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The Heterodyne Instrument for the Far Infrared (HIFI) onboard the Herschel Space Observatory allows the first observations of light diatomic molecules at high spectral resolution and in multiple transitions. Here, we report deep integrations using HIFI in different lines of hydrides towards the high-mass star forming region AFGL 2591. Detected are CH, CH^+, NH, OH^+, H_2O^+, while NH^+ and SH^+ have not been detected. All molecules except for CH and CH^+ are seen in absorption with low excitation temperatures and at velocities different from the systemic velocity of the protostellar envelope. Surprisingly, the $CH(J_{F,P} = 3/2_{2,-} - 1/2_{1,+})$ and $CH^+(J = 1-0, J = 2-1)$ lines are detected in emission at the systemic velocity. We can assign the absorption features to a foreground cloud and an outflow lobe, while the CH and CH^+ emission stems from the envelope. The observed abundance and excitation of CH and CH^+ can be explained in the scenario of FUV irradiated outflow walls, where a cavity etched out by the outflow allows protostellar FUV photons to irradiate and heat the envelope at larger distances driving the chemical reactions that produce these molecules.

Accepted by Astronomy and Astrophysics (HIFI first results issue)

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Spitzer View of Young Massive Stars in the LMC H II Complexes. II. N 159

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The H II complex N 159 in the Large Magellanic Cloud (LMC) is used to study massive star formation in different environments, as it contains three giant molecular clouds (GMCs) that have similar sizes and masses but exhibit different intensities of star formation. We identify candidate massive young stellar objects (YSOs) using infrared photometry, and model their SEDs to constrain mass and evolutionary state. Good fits are obtained for less evolved Type I, I/II, and II sources. Our analysis suggests that there are massive embedded YSOs in N 159B, a maser source, and several ultracompact H II regions. Massive O-type YSOs are found in GMCs N 159-E and N 159-W, which are associated with ionized gas, i.e., where massive stars formed a few Myr ago. The third GMC, N 159-S, has neither O-type YSOs nor evidence of previous massive star formation. This correlation between current and antecedent formation of massive stars suggests that energy feedback is relevant. We present evidence that N 159-W is forming YSOs spontaneously, while collapse in N 159-E may be triggered. Finally, we compare star formation rates determined from YSO counts with those from integrated Hα and 24 μm luminosities and expected from gas surface densities. Detailed dissection of extragalactic GMCs like the one presented here is key to revealing the physics underlying commonly used star formation scaling laws.

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http://www.astro.virginia.edu/∼cc5ye/n159yso.pdf

R CrA SMM 1A: Fragmentation in A Prestellar Core

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We report the discovery of multiple condensations in the prestellar core candidate SMM 1A in the R CrA cloud, which may represent the earliest phase of core fragmentation observed thus far. The separation between the condensations is between 1000 and 2100 AU, and their masses range from about 0.1 to 0.2 $M_\odot$. We find that the three condensations have extremely low bolometric luminosities ($< 0.1\,L_\odot$) and temperatures (< 20 K), indicating that these are young sources that have yet to form protostars. We suggest that these sources were formed through the fragmentation of an elongated prestellar core. Our results, in concert with other observed protostellar binary systems with separations in the scale of 1000 AU, support the scenario that prompt fragmentation in the isothermal collapse phase is an efficient mechanism for wide binary star formation, while the fragmentation in the subsequent adiabatic phase may be an additional mechanism for close (≤ 100 AU) binary star formation.

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Herschel observations of deuterated water towards Sgr B2(M)

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Observations of HDO are an important complement for studies of water, because they give strong constraints on the formation processes – grain surfaces versus energetic process in the gas phase, e.g. in shocks. The HIFI observations of multiple transitions of HDO in Sgr B2(M) presented here allow the determination of the HDO abundance throughout the envelope, which has not been possible before with ground-based observations only. The abundance structure has been modeled with the spherical Monte Carlo radiative transfer code RATRAN, which also takes radiative pumping by continuum emission from dust into account. The modeling reveals that the abundance of HDO rises steeply with temperature from a low abundance (2.5×10^{-11}) in the outer envelope at temperatures below 100 K through a medium abundance (1.5×10^{-9}) in the inner envelope/outer core, at temperatures between 100 and 200 K, and finally a high abundance (3.5×10^{-9}) at temperatures above 200 K in the hot core.

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A Near-Infrared Spectroscopic Survey of Class I Protostars

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We present the results of a near-IR spectroscopic survey of 110 Class I protostars observed from 0.80 μm to 2.43 μm at a spectroscopic resolution of R=1200. This survey is unique in its selection of targets from the whole sky, its sample size, wavelength coverage, depth, and sample selection. We find that Class I objects exhibit a wide range of lines and continuum spectroscopic features. 85% of Class I protostars exhibit features indicative of mass accretion, and we found that the veiling excess, CO emission, and Br γ emission are closely related. We modeled the spectra to estimate the veiling excess (r_k) and extinction to each target. We also used near-IR colors and emission line ratios, when available, to also estimate extinction. In the course of this survey, we observed the spectra of 10 FU Orionis-like objects, including 2 new ones, as well as 3 Herbig Ae type stars among our Class I YSOs. We used photospheric absorption lines, when available, to estimate the spectral type of each target. Although most targets are late type stars, there are several A and F-type stars in our sample. Notably, we found no A or F class stars in the Taurus-Auriga or Perseus star forming regions. There are several cases where the observed CO and/or water absorption bands are deeper than expected from the photospheric spectral type. We find a correlation between the appearance of the reflection nebula, which traces the distribution of material on very large scales, and the near-IR spectrum, which probes smaller scales. All of the FU Orionis-like objects are associated with reflection nebulae. The spectra of the components of spatially resolved protostellar binaries tend to be very similar. In particular both components tend to have similar veiling and H_2 emission, inconsistent with random selection from the sample as a whole. There is a strong correlation between [Fe II] and H_2 emission, supporting previous results showing that H_2 emission in the spectra of young stars is usually shock excited by stellar winds.

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The Age, Stellar Content and Star Formation Timescale of the B59 Dense Core

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We have investigated the stellar content of Barnard 59 (B59), the most active star-forming core in the Pipe Nebula. Using the SpeX spectrograph on the NASA Infrared Telescope Facility, we obtained moderate resolution, near-infrared (NIR) spectra for 20 candidate Young Stellar Objects (YSOs) in B59 and a representative sample of NIR and mid-IR bright sources distributed throughout the Pipe. Measuring luminosity and temperature sensitive features in these spectra, we identified likely background giant stars and measured each star's spectral type, extinction, and NIR continuum excess.

To measure B59's age, we place its candidate YSOs in the Hertzsprung-Russell (HR) diagram and compare their location to YSOs in several well studied star forming regions, as well as predictions of pre-main sequence evolutionary models. We find that B59 is composed of late type (K4-M6) low-mass (0.9–0.1 $M_\odot$) YSOs whose median stellar age is comparable to, if not slightly older than, that of YSOs within the ρ Oph, Taurus, and Chameleon star forming regions. Deriving absolute age estimates from pre-main sequence models computed by D'Antona et al., and accounting only for statistical uncertainties, we measure B59's median stellar age to be 2.6±0.8 Myrs. Including potential systematic effects increases the error budget for B59's median (DM98) stellar age to $2.6^{+4.1}_{-2.6}$ Myrs. We also find that the relative age orderings implied by pre-main sequence evolutionary tracks depend on the range of stellar masses sampled, as model isochrones possess significantly different mass dependencies.

The maximum likelihood median stellar age we measure for B59, and the region's observed gas properties, suggest

that the B59 dense core has been stable against global collapse for roughly 6 dynamical timescales, and is actively forming stars with a star formation efficiency per dynamical time of ∼6%. While the ∼150% uncertainties associated with our age measurement propagate directly into these derived star formation timescales, the maximum likelihood values nonetheless agree well with recent star formation simulations that incorporate various forms of support against collapse, such as sub-critical magnetic fields, outflows, and radiative feedback from protostellar heating.

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Abundances in the Herbig Ae star HD 101412; Abundance anomalies: Lambda Boo-Vega characteristics?

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Context: Recent attention has been directed to abundance variations among very young stars.
Aims: To perform a detailed abundance study of the Herbig Ae star HD 101412, taking advantage of its unusually sharp spectral lines.
Methods: High-resolution spectra are measured for accurate wavelengths and equivalent widths. Balmer-line fits and ionization equlibria give a relation between Teff, and log(g). Abundance anomalies and uncertain reddening preclude the use of spectral type or photometry to fix Teff. Excitation temperatures are used to break the degeneracy between Teff and log(g).
Results: Strong lines are subject to an anomalous saturation that cannot be removed by assuming a low microturbulence. By restricting the analysis to weak ($\leq$ 20mA) lines, we find consistent results for neutral and ionized species, based on a model with Teff = 8300K, and log(g)=3.8. The photosphere is depleted in the most refractory elements, while volatiles are normal or, in the case of nitrogen, overabundant with respect to the sun. The anomalies are unlike those of Ap or Am stars.
Conclusions: We suggest the anomalous saturation of strong lines arises from heating of the upper atmospheric layers by infalling material from a disk. The overall abundance pattern may be related to those found for the Lambda Boo stars, though the depletions of the refractory elements are milder, more like those of Vega. However, the intermediate volatile zinc is depleted, precluding a straightforward interpretation of the abundance pattern in terms of gas-grain separation.

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A submillimetre survey of the kinematics of the Perseus molecular cloud – III. Clump kinematics

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We explore the kinematic properties of dense continuum clumps in the Perseus molecular cloud, derived from our wide-field $C^{18}O$ $J = 3 \rightarrow 2$ data across four regions – NGC 1333, IC348/HH211, L1448 and L1455. Two distinct populations are examined, identified using the automated algorithms CLFIND (85 clumps) and GAUSSCLUMPS (122 clumps) on existing SCUBA 850 μm data. These kinematic signatures are compared to the clumps' dust continuum properties. We calculate each clump's non-thermal linewidth and virial mass from the associated $C^{18}O$ $J = 3 \rightarrow 2$ spectrum. The clumps have supersonic linewidths, $\langle \sigma_{\rm NT}/c_{\rm s} \rangle = 1.76 \pm 0.09$ (CLFIND population) and 1.71 ± 0.05 (with

GAUSSCLUMPS). The linewidth distributions suggest the $C^{18}O$ line probes a lower-density 'envelope' rather than a dense inner core. Similar linewidth distributions for protostellar and starless clumps implies protostars do not have a significant impact on their immediate environment. The proximity to an active young stellar cluster seems to affect the linewidths: those in NGC 1333 are greater than elsewhere. In IC348 the proximity to the old IR cluster has little influence, with the linewidths being the smallest of all. The virial analysis suggests that the clumps are bound and close to equipartition, with virial masses similar to the masses derived from the continuum emission. In particular, the starless clumps occupy the same parameter space as the protostars, suggesting they are true stellar precursors and will go on to form stars. We also search for ordered $C^{18}O$ velocity gradients across the face of each core. Approximately one third have significant detections, which we mainly interpret in terms of rotation. However, we note a correlation between the directions of the identified gradients and outflows across the protostars, indicating we may not have a purely rotational signature. The fitted gradients are in the range $\mathcal{G} = 1$ to $16\,\mathrm{km\ s^{-1}\,pc^{-1}}$, larger than found in previous work, probably as a result of the higher resolution of our data and/or outflow contamination. These gradients, if interpreted solely in terms of rotation, suggest that the rotation is not dynamically significant: the ratios of clump rotational to gravitational energy are $\beta_{\mathrm{rot}} \leq 0.02$. Furthermore, derived specific angular momenta are smaller than observed in previous studies, centred around $j \sim 10^{-3}\,\mathrm{km\,s^{-1}\,pc}$, which indicates we have identified lower levels of rotation, or that the $C^{18}O$ $J = 3 \rightarrow 2$ line probes conditions significantly denser and/or colder than $n \sim 10^5\,\mathrm{cm^{-3}}$ and $T \sim 10\,\mathrm{K}$.

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Tomographic reconstruction of the three-dimensional structure of the HH30 jet

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The physical parameters of Herbig-Haro (HH) jets are usually determined from emission-line ratios, obtained from spectroscopy or narrowband imaging, assuming that the emitting region is homogeneous along the line of sight. Under the more general hypothesis of axisymmetry, we apply tomographic reconstruction techniques to the analysis of HH jets. We use data of the HH30 jet taken by Hartigan and Morse with the Hubble Space Telescope using the slitless spectroscopy technique. Using a non-parametric Tikhonov regularization technique, we determine the volumetric emission-line intensities of the [S II] 6716,6731, [O I] 6300, and [N II] 6583 forbidden emission lines. From our tomographic analysis of the corresponding line ratios, we produce ?three-dimensional? images of the physical parameters. The reconstructed density, temperature, and ionization fraction present much steeper profiles than those inferred using the assumption of homogeneity. Our technique reveals that the reconstructed jet is much more collimated than the observed one close to the source (a width ∼5 AU versus ∼20 AU at a distance of 10 AU from the star), while they have similar widths at larger distances. In addition, our results show a much more fragmented and irregular jet structure than the classical analysis, suggesting that the ejection history of the jet from the star-disk system has a shorter timescale component (∼some months) superimposed on a longer, previously observed timescale (of a few years). Finally, we discuss the possible application of the same technique to other stellar jets and planetary nebulae.

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The origin of the [C II] emission in the S140 PDRs - new insights from HIFI

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Using *Herschel's* HIFI instrument, we observe [C II] along a cut through S140, as well as high-J transitions of CO and HCO^+ at two positions on the cut, corresponding to the externally irradiated ionization front and the embedded massive star-forming core IRS1. The HIFI data were combined with available ground-based observations and modeled using the KOSMA-τ model for photon-dominated regions. We derive the physical conditions in S140 and in particular the origin of [C II] emission around IRS1. We identify three distinct regions of [C II] emission from the cut, one close to the embedded source IRS1, one associated with the ionization front, and one further into the cloud. The line emission can be understood in terms of a clumpy model of photon-dominated regions. At the position of IRS1, we identify at least two distinct components contributing to the [C II] emission, one of them a small, hot component, which can possibly be identified with the irradiated outflow walls. This is consistent with the [C II] peak at IRS1 coinciding with shocked H_2 emission at the edges of the outflow cavity. We note that previously available observations of IRS1 can be reproduced well by a single-component KOSMA-τ model. Thus, it is HIFI's unprecedented spatial and spectral resolution, as well as its sensitivity that has allowed us to uncover an additional hot gas component in the S140 region.

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The *Spitzer* c2d Survey of Nearby Dense Cores. IX. Discovery of a Very Low Luminosity Object Driving a Molecular Outflow in the Dense Core L673-7

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We present new infrared, submillimeter, and millimeter observations of the dense core L673-7 and report the discovery of a low-luminosity, embedded Class 0 protostar driving a molecular outflow. L673-7 is seen in absorption against the mid-infrared background in 5.8, 8, and 24 μm *Spitzer* images, allowing for a derivation of the column density profile and total enclosed mass of L673-7, independent of dust temperature assumptions. Estimates of the core mass from these absorption profiles range from $0.2 - 4.5$ $M_\odot$. Millimeter continuum emission indicates a mass of ~ 2 $M_\odot$, both from a direct calculation assuming isothermal dust and from dust radiative transfer models constrained by the millimeter observations. We use dust radiative transfer models to constrain the internal luminosity of L673-7, defined to be the luminosity of the central source and excluding the luminosity from external heating, to be $L_{int} = 0.01 - 0.045$ $L_\odot$, with $L_{int} \sim 0.04$ $L_\odot$ the most likely value. L673-7 is thus classified as a very low luminosity object (VeLLO), and is among the lowest luminosity VeLLOs yet studied. We calculate the kinematic and dynamic properties of the molecular outflow in the standard manner. From the outflow properties and standard assumptions regarding the driving of outflows, we calculate the time-averaged protostellar mass accretion rate, total protostellar mass accreted, and expected accretion luminosity to be $\langle \dot{M}_{\rm acc} \rangle \geq 1.2 \times 10^{-6} \frac{\sin i}{\cos^2 i}$ $M_\odot$ yr^{-1}, $M_{\rm acc} \geq 0.07 \frac{1}{\cos i}$ $M_\odot$ and $L_{acc} \geq 0.36$ $L_\odot$, respectively. The discrepancy between this calculated L_{acc} and the L_{int} derived from dust radiative transfer models indicates that the current accretion rate is much lower than the average rate over the lifetime of the outflow. Although the protostar embedded within L673-7 is consistent with currently being substellar, it is unlikely to remain as such given the substantial mass reservoir remaining in the core.

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A Dynamical Study of Suspected Runaway Stars as Traces of Past Supernova Explosions in the Region of the Scorpius-Centaurus OB association

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We address the question of identifying possible past supernovae events taking place in the region of the Scorpius-Centaurus (Sco-Cen) OB association based on stars proposed by Hoogerwerf et al. (2001). With this purpose, we obtained a time series of high resolution spectra of six stars (HIP 42038, HIP 46950, HIP 48943, HIP 69491, HIP 76013, HIP 82868) which, according to Hoogerwerf et al. (2001), may have been runaway stars with origin in the region of the Sco-Cen association. This includes also the nearby young open clusters IC 2391 and IC 2602. If confirmed, such supernovae events could, in principle, have played a role in triggering the formation of some small stellar groups thought to be associated with the Sco-Cen association. Our analysis shows that excepting HIP 48943 the remaining stars are spectroscopic binary systems. For HIP 46950 and HIP 69491 this was already noted by other authors. Our high resolution spectra allowed us to obtain the radial velocities for all the stars which, combined with their proper motions and parallaxes from HIPPARCOS, provide a means to investigate, by retracing their orbits, if the Sco-Cen region was, in fact, the origin of these stars. We find that none of these systems was originated in the Sco-Cen region. Exploring the possibility that the birthplace of the studied stars occurred in the clusters IC 2391 and IC 2602, we noticed that at the epoch of $2 - 3$ Myr ago these clusters were at a distance comparable with their tidal radii.

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Low-mass Star Formation

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I briefly review recent observations of regions forming low mass stars. The discussion is cast in the form of seven questions that have been partially answered, or at least illuminated, by new data. These are the following: where do stars form in molecular clouds; what determines the IMF; how long do the steps of the process take; how efficient is star formation; do any theories explain the data; how are the star and disk built over time; and what chemical changes accompany star and planet formation. I close with a summary and list of open questions.

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FLAMINGOS Near Infra-Red Survey of The Serpens Cloud Main Core

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We obtained JHK images and low-resolution JH spectra in the embedded young cluster in the Serpens cloud Main core (also known as Serpens North). We determined spectral types (SpT) for 15 previously identified cluster members (for 5 of them for the first time), 1 new candidate, and 11 stars that appear to be field interlopers. Extinction, for which we derived an analytical expression, was obtained by taking SpT and near-IR excess into account. The location on the Hertzsprung-Russell diagram indicates that we probed a low-mass population of the cloud (0.05 - 1.5 Msol), including 1 – 3 brown dwarfs. We used our individually determined photospheric parameters to analyze the ISO and the Spitzer determined spectral energy distribution classes. The latter were correlated with the age and location of the sources in the cloud. We find that most flat objects from our study (4 out of 5) have SEDs consistent with reddened classical T Tau stars; however, when comparing to the thick disk SEDs of lower mass M-type objects, we find that the flat ones show more excess, perhaps indicating an earlier evolutionary stage. We determined a median age for the cluster to be 1 Myr for distance of 380 pc, and 3 Myr for a less likely distance of 260 pc. The core of the cluster is on average younger than the rest of the cluster. We do not find objects with disks past 5 Myr. We do find diskless, X-ray bright objects younger than 1 Myr, as was also noted in the study of Winston et al (2009). We find two groups of young objects associated with dark filaments, indicating that star formation was not always confined to the core.

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http://ster.kuleuven.be/∼nadya/serpens_highres.pdf

A few days before the end of the 2008 extreme outburst of EX Lup : accretion shocks and a smothered stellar corona unveiled by XMM-Newton

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EX Lup is a pre-main sequence star that exhibits repetitive and irregular optical outbursts driven by an increase in the mass accretion rate in its circumstellar disk. In mid-January 2008, EX Lup, the prototype of the small class of eruptive variables called EXors, began an extreme outburst that lasted seven months. We attempt to characterize the X-ray and UV emission of EX Lup during this outburst. We observed EX Lup during about 21 h with *XMM-Newton*, simultaneously in X-rays and UV, on August 10–11, 2008 – a few days before the end of its 2008 outburst – when the optical flux of EX Lup remained about 4 times above its pre-outburst level. We detected EX Lup in X-rays with an observed flux in the 0.2–10 keV energy range of 5.4×10^{-14} erg s^{-1} cm^{-2} during a low-level period. This observed flux increased by a factor of four during a flaring period that lasted about 2 h. The observed spectrum of the low-level period is dominated below ∼1.5 keV by emission from a relatively cool plasma (∼4.7 MK) that is lightly absorbed ($N_{\rm H} \simeq 3.6 \times 10^{20}$ cm^{-2}) and above ∼1.5 keV by emission from a plasma that is ∼ten times hotter and affected by a photoelectric absorption that is 75 times larger. The intrinsic X-ray luminosity of the relatively cool plasma is $\sim 4 \times 10^{28}$ erg s^{-1}. The intrinsic X-ray luminosity of EX Lup, $\sim 3.4 \times 10^{29}$ erg s^{-1}, is hence dominated by emission from the hot plasma. During the X-ray flare, the emission measure and the intrinsic X-ray luminosity of this absorbed plasma component is five times higher than during the low-level period. We detected UV variability on timescales ranging from less than one hour up to about four hours. We show from simulated light curves that the power spectral density of the UV light curve can be modeled with a red-noise spectrum with a power-law index of 1.39 ± 0.06. None of the UV events observed on August 10–11, 2008 correlate unambiguously with simultaneous X-ray peaks. The soft X-ray spectral component is most likely associated with accretion shocks, as opposed to jet activity, given the absence of forbidden emission lines of low-excitation species (e.g., [O I]) in optical spectra of EX Lup obtained during outburst. The hard X-ray spectral component, meanwhile, is most likely associated with a smothered stellar corona. The UV emission is reminiscent of accretion events, such as those already observed with the Optical/UV Monitor from other accreting pre-main sequence stars, and is evidently dominated by emission from accretion hot spots. The large photoelectric absorption of the active stellar corona is most likely due to high-density gas above the corona in accretion funnel flows.

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Chronology of star formation and disk evolution in the Eagle Nebula

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Massive star-forming regions are characterized by intense ionizing fluxes, strong stellar winds and, occasionally, supernovae explosions, all of which have important effects on the surrounding media, on the star-formation process and on the evolution of young stars and their circumstellar disks. We present a multiband study of the massive young cluster NGC6611 and its parental cloud (the Eagle Nebula) with the aim of studying how OB stars affect the early stellar evolution and the formation of other stars. We search for evidence of: triggering of star formation by the massive stars inside NGC6611 on a large spatial scale (about 10 parsec) and ongoing disk photoevaporation in NGC6611 and how its efficiency depends on the mass of the central stars. We assemble a multiband catalog of the Eagle Nebula with photometric data, ranging from B band to 8.0 micron, and X-ray data obtained with two new and one archival CHANDRA/ACIS-I observation. We select the stars with disks from infrared photometry and disk-less ones from X-ray emission, which are associated both with NGC6611 and the outer region of the Eagle Nebula. We study induced photoevaporation searching for the spatial variation of disk frequency for distinct stellar mass ranges. The triggering of star formation by OB stars has been investigated by deriving the history of star formation across the nebula. We find evidence of sequential star formation in the Eagle Nebula going from the southeast (2.6 Myears) to the northwest (0.3 Myears), with the median age of NGC6611 members of about 1 Myear. In NGC6611, we observe a drop of the disk frequency close to massive stars (up to an average distance of 1 parsec), without observable effects at larger distances. Furthermore, disks are more frequent around low-mass stars (less equal to one solar mass) than around high-mass stars, regardless of the distance from OB stars. The star formation chronology we find in the Eagle Nebula does not support the hypothesis of a large-scale process triggered by OB stars in NGC6611. Instead, we speculate that it was

triggered by the encounter (about 3 Myears ago) with a giant molecular shell created by supernovae explosions about 6 Myears ago. We find evidence of disk photoevaporation close to OB stars, where disks are heated by incident extreme ultraviolet (EUV) radiation. No effects are observed at large distances from OB stars, where photoevaporation is induced by the far ultraviolet (FUV) radiation, and long timescales are usually required to completely dissipate the disks.

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A Spitzer Search For Planetary-Mass Brown Dwarfs With Circumstellar Disks: Candidate Selection

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We report on initial results from a *Spitzer* program to search for very low-mass brown dwarfs in Ophiuchus. This program is an extension of an earlier study by Allers et al. which had resulted in an extraordinary success rate, 18 confirmed out of 19 candidates. Their program combined near-infrared and Spitzer photometry to identify objects with very cool photospheres together with circumstellar disk emission to indicate youth. Our new program has obtained deep IRAC photometry of a 0.5 deg^2 field that was part of the original Allers et al. study. We report 18 new candidates whose luminosities extend down to 10^{-4} $L_\odot$ which suggests masses down to $\sim 2\ M_J$ if confirmed. We describe our selection techniques, likely contamination issues, and follow-on photometry and spectroscopy that are in progress.

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A Mapping Survey of Dense Clumps Associated with Embedded Clusters II : Can Clump-Clump Collisions Induce Stellar Clusters?

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We report the $H^{13}CO^+$ (J=1–0) survey observations toward embedded clusters obtained using the Nobeyama 45m telescope, which were performed to follow up our previous study in the $C^{18}O$ survey with a dense gas tracer. Our aim is to address the evolution of cluster-forming clumps. We observed the same 14 clusters in $C^{18}O$, which are located at distances from 0.3 to 2.1 kpc with 27″ resolution (corresponding to Jeans length for most of our targets) in $H^{13}CO^+$. We detected the 13 clumps in $H^{13}CO^+$ line emission and obtained the physical parameters of the clumps with radii of 0.24–0.75 pc, masses of 100–1400 $M_\odot$, and velocity widths in FWHM of 1.5–4.0 km s^{-1}. The mean density is $\sim 3.9 \times 10^4$ cm^{-3} and the equivalent Jeans length is ~ 0.13 pc at 20 K. We classified the $H^{13}CO^+$ clumps into three types, *Type A*, *Type B*, and *Type C* according to the relative locations of the $H^{13}CO^+$ clumps and the clusters (see our previous study). Our classification represents an evolutionary trend of cluster-forming clumps because dense clumps are expected to be converted into stellar constituents, or dispersed by stellar activities. We found a similar but clearer trend than our previous results for derived star formation efficiencies to increase from *Type A* to *C* in the $H^{13}CO^+$ data, and for the dense gas regions within the clumps traced by $H^{13}CO^+$ to be sensitive to the physical evolution of clump-cluster systems. In addition, we found that four out of 13 $H^{13}CO^+$ clumps which we named “DVSOs” (Distinct Velocity Structure Objects) have distinct velocity gradients at the central parts of them, i.e., at the location of the embedded clusters. Assuming that the velocity gradients represent the rigid-like rotation of the clumps, we calculated the virial parameter of the $H^{13}CO^+$ clumps by taking into account the contribution of rotation, and found that the DVSOs tend to be gravitationally unbound. In order to explain the above physical properties for DVSOs in a consistent way, we propose a clump-clump collision model as a possible mechanism for triggering formation of clusters.

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Astrometry of H_2O Masers in Nearby Star-Forming Regions with VERA — IV. L1448C

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We have carried out multi-epoch VLBI observations with VERA (VLBI Exploration of Radio Astrometry) of the 22 GHz H_2O masers associated with a Class 0 protostar L1448C in the Perseus molecular cloud. The maser features trace the base of collimated bipolar jet driven by one of the infrared counter parts of L1448C named as L1448C(N) or L1448-mm A. We detected possible evidences for apparent acceleration and precession of the jet according to the three-dimensional velocity structure. Based on the phase-referencing VLBI astrometry, we have successfully detected an annual parallax of the H_2O maser in L1448C to be 4.31±0.33 milliarcseconds (mas) which corresponds to a distance of 232±18 pc from the Sun. The present result is in good agreement with that of another H_2O maser source NGC 1333 SVS13A in the Perseus molecular cloud, 235 pc. It is also consistent with the photometric distance, 220 pc. Thus, the distance to the western part of the Perseus molecular cloud complex would be constrained to be about 235 pc rather than the larger value, 300 pc, previously reported.

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Evolution of Massive Protostars via Disk Accretion

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Mass accretion onto (proto-)stars at high accretion rates $\dot{M}_* > 10^{-4}\ M_\odot\ \mathrm{yr}^{-1}$ is expected in massive star formation. We study the evolution of massive protostars at such high rates by numerically solving the stellar structure equations. In this paper we examine the evolution via disk accretion. We consider a limiting case of "cold" disk accretion, whereby most of the stellar photosphere can radiate freely with negligible backwarming from the accretion flow, and the accreting material settles onto the star with the same specific entropy as the photosphere. We compare our results to the calculated evolution via spherically symmetric accretion, the opposite limit, whereby the material accreting onto the star contains the entropy produced in the accretion shock front. We examine how different accretion geometries affect the evolution of massive protostars. For cold disk accretion at $10^{-3}\ M_\odot\ \mathrm{yr}^{-1}$ the radius of a protostar is initially small, $R_* \simeq$ a few $R_\odot$. After several solar masses have accreted, the protostar begins to bloat up and for $M_* \simeq 10\ M_\odot$ the stellar radius attains its maximum of $30 - 400\ R_\odot$. The large radius $\sim$100 $R_\odot$ is also a feature of spherically symmetric accretion at the same accreted mass and accretion rate. Hence, expansion to a large radius is a robust feature of accreting massive protostars. At later times the protostar eventually begins to contract and reaches the Zero-Age Main-Sequence (ZAMS) for $M_* \simeq 30\ M_\odot$, independent of the accretion geometry. For accretion rates exceeding several $10^{-3}\ M_\odot\ \mathrm{yr}^{-1}$ the protostar never contracts to the ZAMS. The very large radius of several 100s $R_\odot$ results in a low effective temperature and low UV luminosity of the protostar. Such bloated protostars could well explain the existence of bright high-mass protostellar objects, which lack detectable H II regions.

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Structure and Composition of Two Transitional Circumstellar Disks in Corona Australis

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The late stages of evolution of the primordial circumstellar disks surrounding young stars are poorly understood, yet vital to constrain theories of planet formation. We consider basic structural models for the disks around two ∼10 Myr-old members of the nearby RCrA association, RX J1842.9-3532 and RX J1852.3-3700. We present new arcsecond-resolution maps of their 230 GHz continuum emission from the Submillimeter Array and unresolved CO(3-2) spectra from the Atacama Submillimeter Telescope Experiment. By combining these data with broadband fluxes from the literature and infrared fluxes and spectra from the catalog of the Formation and Evolution of Planetary Systems (FEPS) Legacy program on the *Spitzer* Space Telescope, we assemble a multiwavelength data set probing the gas and dust disks. Using the Monte Carlo radiative transfer code `RADMC` to model simultaneously the SED and millimeter continuum visibilities, we derive basic dust disk properties and identify an inner cavity of radius 16 AU in the disk around RX J1852.3-3700. We also identify an optically thin 5 AU cavity in the disk around RX J1842.9-3532, with a small amount of optically thick material close to the star. The molecular line observations suggest an intermediate disk inclination in RX J1842.9-3532, consistent with the continuum emission. In combination with the dust models, the molecular data allow us to derive a lower CO content than expected, suggesting that the process of gas clearing is likely underway in both systems, perhaps simultaneously with planet formation.

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A hot compact dust disk around a massive young stellar object

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Circumstellar disks are an essential ingredient of the formation of low-mass stars. It is unclear, however, whether the accretion-disk paradigm can also account for the formation of stars more massive than about 10 solar masses, in which strong radiation pressure might halt mass infall. Massive stars may form by stellar merging, although more recent theoretical investigations suggest that the radiative-pressure limit may be overcome by considering more complex, nonspherical infall geometries. Clear observational evidence, such as the detection of compact dusty disks around massive young stellar objects, is needed to identify unambiguously the formation mode of the most massive stars. Here we report near-infrared interferometric observations that spatially resolve the astronomical unit-scale distribution of hot material around a high-mass ($\sim$ 20 solar masses) young stellar object. The image shows an elongated structure with a size of about 13×19 astronomical units, consistent with a disk seen at an inclination angle of 45°. Using geometric and detailed physical models, we found a radial temperature gradient in the disk, with a dust-free region less than 9.5 astronomical units from the star, qualitatively and quantitatively similar to the disks observed in low-mass star formation. Perpendicular to the disk plane we observed a molecular outflow and two bow shocks, indicating that a bipolar outflow emanates from the inner regions of the system.

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C^+ detection of warm dark gas in diffuse clouds

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We present the first results of the *Herschel* open time key program, **G**alactic **O**bservations of **T**erahertz **C**$^+$ (**GOT C+**) survey of the [CII] $^2P_{3/2}$–$^2P_{1/2}$ fine-structure line at 1.9 THz (158 μm) using the HIFI instrument on *Herschel*. We detected 146 interstellar clouds along sixteen lines–of–sight towards the inner Galaxy. We also acquired HI and CO isotopologue data along each line–of–sight for analysis of the physical conditions in these clouds. Here we analyze 29 diffuse clouds ($A_V < 1.3$ mag.) in this sample characterized by having [CII] and HI emission, but no detectable CO. We find that [CII] emission is generally stronger than expected for diffuse atomic clouds, and in a number of sources is much stronger than anticipated based on their HI column density. We show that excess [CII] emission in these clouds is best explained by the presence of a significant diffuse warm H_2, dark gas, component. This first [CII] 158 μm detection of warm dark gas demonstrates the value of this tracer for mapping this gas throughout the Milky Way and in galaxies.

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Tracing Turbulent Ambipolar Diffusion in Molecular Clouds

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Though flux freezing is a good approximation frequently assumed for molecular clouds, ambipolar diffusion (AD) is inevitable at certain scales. The scale at which AD sets in can be a crucial parameter for turbulence and the star formation process. However, both observation and simulation of AD are very challenging and our knowledge of it is very limited. We recently proposed that the difference between ion and neutral velocity spectra is a signature of turbulent AD and can be used to estimate the AD scales and magnetic field strengths. Here, we present observational evidence showing that this difference between the velocity dispersions from coexistent ions and neutrals is indeed correlated with magnetic field strength.

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Modeling the Hα line emission around classical T Tauri stars using magnetospheric accretion and disk wind models

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Spectral observations of classical T Tauri stars show a wide range of line profiles, many of which reveal signs of matter inflow and outflow. Hα is the most commonly observed line profile due to its intensity, and it is highly dependent on the characteristics of the surrounding environment of these stars. Our aim is to analyze how the Hα line profile is affected by the various parameters of our model which contains both the magnetospheric and disk wind contributions to the Hα flux. We used a dipolar axisymmetric stellar magnetic field to model the stellar magnetosphere and a modified Blandford & Payne model was used in our disk wind region. A three-level atom with continuum was used to calculate the required Hydrogen level populations. We use the Sobolev approximation and a ray-by-ray method to calculate the integrated line profile. Through an extensive study of the model parameter space, we have investigated the contribution of many of the model parameters on the calculated line profiles. Our results show that the Hα line is strongly dependent on the densities and temperatures inside the magnetosphere and the disk wind region. The bulk of the flux comes, most of the time, from the magnetospheric component for standard classical T Tauri stars parameters, but the disk wind contribution becomes more important as the mass accretion rate, the temperatures and densities inside the disk wind increase. We have also found that most of the disk wind contribution to the Halpha line is emitted at the innermost region of the disk wind. Models that take into consideration both inflow and outflow of matter are a necessity to fully understand and describe classical T Tauri stars.

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HH 223: a parsec-scale H_2 outflow in the star-forming region L723

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The dark cloud Lynds 723 (L723) is a low-mass star-forming region where one of the few known cases of a quadrupolar CO outflow has been reported. Two recent works have found that the radio continuum source VLA 2, towards the centre of the CO outflow, is actually a multiple system of young stellar objects (YSOs). Several line-emission nebulae that lie projected on the east-west CO outflow were detected in narrow-band Hα and [S II] images. The spectra of the knots are characteristic of shock-excited gas (Herbig-Haro spectra), with supersonic blueshifted velocities, which suggests an optical outflow also powered by the VLA 2 YSO system of L723.

Our aim is to study L723 in the near-infrared and look for line-emission nebulae associated with the optical and CO outflows. We imaged a field of $\sim\ 5' \times 5'$ centred on HH 223, which includes the whole region of the quadrupolar CO outflow with narrow-band filters centred on the [Fe II] 1.644 μm and H_2 2.122 μm lines, together with off-line H_c and K_c filters. The [Fe II] and H_2 line-emission structures were identified after extracting the continuum contribution, if any. Their positions were determined from an accurate astrometry of the images.

The H_2 line-emission structures appear distributed over a region of $5.5'$ ($\sim$ 0.5 pc for a distance of 300 pc) at both sides of the VLA 2 YSO system, with an S-shape morphology, and are projected onto the east-west CO outflow. Most of them were resolved in smaller knotty substructures. The [Fe II] emission only appears associated with HH 223.

An additional nebular emission from the continuum in H_c and K_c appears associated with HH 223-K1, the structure closest to the VLA 2 YSO system, and could be tracing the cavity walls. We propose that the H_2 structures form part of a large-scale near-infrared outflow, which is also associated with the VLA 2 YSO system. The current data do not allow us to discern which of the YSOs of VLA 2 is powering this large scale optical/near-infrared outflow.

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On the fragmentation criteria of self-gravitating protoplanetary discs

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We investigate the fragmentation criterion in massive self-gravitating discs. We present new analysis of the fragmentation conditions which we test by carrying out global three-dimensional numerical simulations. Whilst previous work has placed emphasis on the cooling timescale in units of the orbital timescale, β, we find that at a given radius the surface mass density (i.e. disc mass and profile) and star mass also play a crucial role in determining whether a disc fragments or not as well as where in the disc fragments form. We find that for shallow surface mass density profiles ($p < 2$, where $\Sigma \propto R^{-p}$), fragments form in the outer regions of the disc. However for steep surface mass density profiles ($p \gtrsim 2$), fragments form in the inner regions of a disc. In addition, we also find that the critical value of the cooling timescale in units of the orbital timescale, $\beta_{\rm crit}$, found in previous simulations is only applicable to certain disc surface mass density profiles and for particular disc radii and is not a general rule for all discs. We find an empirical fragmentation criteria between the cooling timescale in units of the orbital timescale, β, the surface mass density, the star mass and the radius.

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High Resolution Spectroscopy during Eclipse of the Young Substellar Eclipsing Binary 2MASS 0535−0546. I. Primary Spectrum: Cool Spots versus Opacity Uncertainties

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We present high-resolution Keck optical spectra of the very young substellar eclipsing binary 2MASS J05352184−0546085, obtained during eclipse of the lower-mass (secondary) brown dwarf. The observations yield the spectrum of the higher-mass (primary) brown dwarf alone, with negligible (∼1.6%) contamination by the secondary. We perform a simultaneous fine-analysis of the TiO-ϵ band and the red lobe of the KI doublet, using state-of-the-art PHOENIX DUSTY and COND synthetic spectra. Comparing the effective temperature and surface gravity derived from these fits to the *empirically* determined surface gravity of the primary ($\log g = 3.5$) then allows us to test the model spectra as well as probe the prevailing photospheric conditions. We find that: *(1)* fits to TiO-ϵ alone imply $T_{\rm eff} = 2500 \pm 50$K; *(2)* at this $T_{\rm eff}$, fits to KI imply $\log g = 3.0$, 0.5 dex lower than the true value; and *(3)* at the true $\log g$, KI fits yield $T_{\rm eff} = 2650 \pm 50$K, ∼150K higher than from TiO-ϵ alone. On the one hand, these are the trends expected in the presence of cool spots covering a large fraction of the primary's surface (as theorized previously to explain the observed $T_{\rm eff}$ reversal between the primary and secondary). Specifically, our results can be reproduced by an unspotted stellar photosphere with $T_{\rm eff} = 2700$K and (empirical) $\log g = 3.5$, coupled with axisymmetric cool spots that are 15% cooler (2300K), have an effective $\log g = 3.0$ (0.5 dex lower than photospheric), and cover 70% of the surface. On the other hand, the trends in our analysis can also be reproduced by model opacity errors: there are lacks in the synthetic TiO-ϵ opacities, at least for higher-gravity field dwarfs. Stringently discriminating between the two possibilities requires combining

the present results with an equivalent analysis of the secondary (predicted to be relatively unspotted compared to the primary).

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Compact radio sources in the vicinity of the ultracompact HII region G78.4+2.6

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Using the Very Large Array (VLA) at 3.6 cm we identify four new compact radio sources in the vicinity of the cometary HII region G78.4+2.6 (VLA 1). The four compact radio sources (named VLA 2 to VLA 5), have near-infrared counterparts, as seen in the 3.6 μm Spitzer image. One of them (VLA 5) clearly shows evidence of radio variability in a timescale of hours. We explore the possibility that these radio sources are associated with pre-main sequence (PMS) stars in the vicinity of the UC HII region G78.4+2.6. Our results favor the smaller distance value of 1.7 kpc for G78.4+2.6. In addition to the detection of the radio sources in the vicinity of G78.4+2.6, we detected another group of five sources which appear located about $3^{'}$ to the northwest of the HII region. Some of them exhibit extended emission.

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Spectrophotometry of the Huygens Region of the Orion Nebula, the Extended Orion Nebula, and M 43; Scattered Light Systematically Distorts Conditions Derived from Emission-Lines

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We report on medium resolution spectrophotometry of the Orion Nebula region, including for the first time the Extended Orion Nebula and the nearby M 43. The 49 long slit observations were divided into 99 smaller samples, which have allowed determinations of the amount of extinction, extinction corrected Hβ surface brightness, electron temperatures (from [S II], [N II], and [O III]), and electron densities (from [S II] and [Cl III]) throughout much of this complex region.

We verify an earlier conclusion from a radio/optical study that beyond about 5 arcmin from θ^1 Ori C local emission begins to be contaminated by scattering of light from the much brighter central Huygens Region of M 42 and this scattered light component becomes dominant at large distances. This contamination means that the derived properties for the outer regions are not accurate. From comparison of the light from the dominant star in M 43 with the continuum of that nebula (which is almost entirely scattered star light) it is determined that scattered light is enhanced in the blue, which can lead to observed Balmer line ratios that are theoretically impossible and erroneous electron temperatures. This blue scattering of emission-lines is important even in the Huygens Region because it means that at anything except very high spectroscopic resolution the observed lines are a blend of the original and scattered light, with shorter wavelength lines being artificially enhanced. This can lead to over-estimates of the electron temperatures derived from the nebular and auroral line ratios of forbidden lines. This phenomenon is probably applicable to many other H II regions.

We have been able to use extinction-insensitive line ratios, the extinction corrected surface brightness in Hβ, and the equivalent width of the continuum to create for the first time a three dimensional model of the entire M 42, Extended Orion Nebula, and M 43 region. This is an irregular concave blister of ionized gas bounded on the outside by apparent walls where the ionization front has curved almost to the direction of the observer. M 43 is seen to be shielded from illumination by θ^1 Ori C by the northeast portion of the wall bounding M 42.

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A torque formula for non-isothermal Type I planetary migration - II. Effects of diffusion

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We study the effects of diffusion on the non-linear corotation torque, or horseshoe drag, in the two-dimensional limit, focusing on low-mass planets for which the width of the horseshoe region is much smaller than the scale height of the disc. In the absence of diffusion, the non-linear corotation torque saturates, leaving only the Lindblad torque. Diffusion of heat and momentum can act to sustain the corotation torque. In the limit of very strong diffusion, the linear corotation torque is recovered. For the case of thermal diffusion, this limit corresponds to having a locally isothermal equation of state. We present some simple models that are able to capture the dependence of the torque on diffusive processes to within 20% of the numerical simulations.

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The circumstellar environment of the YSO TMR-1 and a revisit to the candidate very low-mass object TMR-1C

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Context. TMR-1 (IRAS 04361+2547) is a class I proto-stellar source located in the nearby Taurus star-forming region. Its circumstellar environment is characterized by extended dust emission with complex structures and conspicuous filaments. A faint companion, called TMR-1C, located near the proto-star was detected in previous studies, but its nature as a very young substellar object remains inconclusive.
Aims. We aim to improve the constraints on the nature of the faint object TMR-1C, and to investigate the process of very low-mass star formation in the TMR-1 system.
Methods. Using very sensitive infrared imaging observations of the TMR-1 system and near-infrared spectroscopy, we compile the spectral energy distribution (SED) of TMR-1C over a much wider wavelength range than possible in previous work. We then compare the spectral energy distribution with models of extincted background stars, young sub-stellar objects, and very low-mass stars with circumstellar disk and envelope emission. We also search for additional low-luminosity sources in the immediate environment of the TMR-1 proto-stellar source. Furthermore, we study the surrounding near-infrared dust morphology, and analyse the emission line spectrum of a filamentary structure in the physical context of a bow-shock model.
Results. We find that the observed SED of TMR-1C can be reproduced by neither an extincted background star, nor available models for a young extremely low-mass ($\lesssim$12M_J) object. Our near-infrared spectrum allows us to infer an effective temperature $\gtrsim$3000K. We achieve a close fit of TMR-1C's SED using radiation transfer models of young stellar objects with circumstellar disks, hence propose that TMR-1C is most likely a very low-mass star with $M \approx 0.1 - 0.2 M_\odot$ surrounded by a circumstellar disk of high inclination, $i > 80°$. Interestingly, we detect an additional very faint source, which we call TMR-1D, that is remarkably symmetrical in terms of position with TMR-1C. Both TMR-1C and TMR-1D may have formed from a common star-formation event, triggered by a powerful outflow or by the collision of primordial proto-stellar disks. The impact of an outflow is traced by molecular hydrogen emission that

we detect from a distinct filament pointing towards TMR-1C. A comparison with C-type bow shock models confirms that the emission is caused by shock excitation.

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A sample of [C II] clouds tracing dense clouds in weak FUV fields observed by *Herschel*

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The [C II] fine–structure line at 158 μm is an excellent tracer of the warm diffuse gas in the ISM and the interfaces between molecular clouds and their surrounding atomic and ionized envelopes. Here we present the initial results from Galactic observations of terahertz C^+ (**GOT C+**), a *Herschel* Key Project devoted to studying the [C II] emission in the Galactic plane using the HIFI instrument. We used the [C II] emission, together with observations of CO, as a probe to understand the effects of newly formed stars on their interstellar environment and characterize the physical and chemical state of the star-forming gas. We collected data along 16 lines–of–sight passing near star–forming regions in the inner Galaxy near longitudes 330° and 20°. We identified fifty–eight [C II] components that are associated with high–column density molecular clouds as traced by ^{13}CO emission. We combined [C II], ^{12}CO, and ^{13}CO observations to derive the physical conditions of the [C II]–emitting regions in our sample of high–column density clouds based on comparing results from a grid of photon dominated region (PDR) models. From this unbiased sample, our results suggest that most of the [C II] emission originates in clouds with H_2 volume densities between $10^{3.5}$ and $10^{5.5}$ cm^{-3} and weak FUV strength ($\chi_0 = 1-10$). We find two regions where our analysis suggests high densities $> 10^5$ cm^{-3} and strong FUV fields ($\chi_0 = 10^4 - 10^6$), likely associated with massive star formation. We suggest that [C II] emission in conjunction with CO isotopes is a good tool for differentiating regions of massive star formation (high densities/strong FUV fields) and regions that are distant from massive stars (lower densities/weaker FUV fields) along the line–of–sight.

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The relation between gas and dust in the Taurus Molecular Cloud

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We report a study of the relation between dust and gas over a 100 deg^2 area in the Taurus molecular cloud. We compare the H_2 column density derived from dust extinction with the CO column density derived from the ^{12}CO and ^{13}CO $J = 1 \rightarrow 0$ lines. We derive the visual extinction from reddening determined from 2MASS data. The comparison is done at an angular size of 200″ , corresponding to 0.14 pc at a distance of 140 pc. We find that the relation between visual extinction A_V and N(CO) is linear between $A_V \simeq 3$ and 10 mag in the region associated with the B213–L1495 filament. In other regions the linear relation is flattened for $A_V > 4$ mag. We find that the presence of temperature gradients in the molecular gas affects the determination of N(CO) by ∼30–70% with the largest difference occurring at large column densities. Adding a correction for this effect and accounting for the observed relation between the column density of CO and CO_2 ices and A_V, we find a linear relationship between the column of carbon monoxide and dust for observed visual extinctions up to the maximum value in our data $\simeq 23$ mag. We have used these data

to study a sample of dense cores in Taurus. Fitting an analytical column density profile to these cores we derive an average volume density of about $1.4 \times 10^4\,\mathrm{cm}^{-3}$ and a CO depletion age of about 4.2×10^5 years. At visual extinctions smaller than $\sim$3 mag, we find that the CO fractional abundance is reduced by up to two orders of magnitude. The data show a large scatter suggesting a range of physical conditions of the gas. We estimate the H_2 mass of Taurus to be about $1.5 \times 10^4\,M_\odot$, independently derived from the A_V and N(CO) maps. We derive a CO integrated intensity to H_2 conversion factor of about $2.1\times10^{20}\,\mathrm{cm}^{-2}(\mathrm{K\ km\ s}^{-1})^{-1}$, which applies even in the region where the [CO]/[H_2] ratio is reduced by up to two orders of magnitude. The distribution of column densities in our Taurus maps resembles a log–normal function but shows tails at large and low column densities. The length scale at which the high–column density tail starts to be noticeable is about 0.4 pc.

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Detectability of giant planets in protoplanetary disks by CO emission lines

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Context. Planets are thought to form in protoplanetary accretion disks around young stars. Detecting a giant planet still embedded in a protoplanetary disk would be very important and give observational constraints on the planet-formation process. However, detecting these planets with the radial velocity technique is problematic owing to the strong stellar activity of these young objects.
Aims. We intend to provide an indirect method to detect Jovian planets by studying near infrared emission spectra originating in the protoplanetary disks around T Tauri stars. Our idea is to investigate whether a massive planet could induce any observable effect on the spectral lines emerging in the disks atmosphere. As a tracer molecule we propose CO, which is excited in the ro-vibrational fundamental band in the disk atmosphere to a distance of $\sim 2 - 3$ AU (depending on the stellar mass) where terrestrial planets are thought to form.
Methods. We developed a semi-analytical model to calculate synthetic molecular spectral line profiles in a protoplanetary disk using a double layer disk model heated on the outside by irradiation by the central star and in the midplane by viscous dissipation due to accretion. 2D gas dynamics were incorporated in the calculation of synthetic spectral lines. The motions of gas parcels were calculated by the publicly available hydrodynamical code FARGO which was developed to study planet-disk interactions.
Results. We demonstrate that a massive planet embedded in a protoplanetary disk strongly influences the originally circular Keplerian gas dynamics. The perturbed motion of the gas can be detected by comparing the CO line profiles in emission, which emerge from planet-bearing to those of planet-free disk models. The planet signal has two major characteristics: a permanent line profile asymmetry, and short timescale variability correlated with the orbital phase of the giant planet. We have found that the strength of the asymmetry depends on the physical parameters of the star-planet-disk system, such as the disk inclination angle, the planetary and stellar masses, the orbital distance, and the size of the disk inner cavity. The permanent line profile asymmetry is caused by a disk in an eccentric state in the gap opened by the giant planet. However, the variable component is a consequence of the local dynamical perturbation by the orbiting giant planet. We show that a forming giant planet, still embedded in the protoplanetary disk, can be detected using contemporary or future high-resolution near-IR spectrographs like VLT/CRIRES and ELT/METIS.

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Milli-arcsecond images of the Herbig Ae star HD 163296

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The very close environments of young stars are the hosts of fundamental physical processes, such as planet formation, star-disk interactions, mass accretion, and ejection. The complex morphological structure of these environments has been confirmed by the now quite rich data sets obtained for a few objects by near-infrared long-baseline interferometry. We gathered numerous interferometric measurements for the young star HD163296 with various interferometers (VLTI, IOTA, KeckI and CHARA), allowing for the first time an image independent of any a priori model to be reconstructed. Using the Multi-aperture image Reconstruction Algorithm (MiRA), we reconstruct images of HD 163296 in the H and K bands. We compare these images with reconstructed images obtained from simulated data using a physical model of the environment of HD 163296. We obtain model-independent H and K-band images of the surroundings of HD 163296. The images present several significant features that we can relate to an inclined asymmetric flared disk around HD 163296 with the strongest intensity at about 4-5 mas. Because of the incomplete spatial frequency coverage, we cannot state whether each of them individually is peculiar in any way. For the first time, milli-arcsecond images of the environment of a young star are produced. These images confirm that the morphology of the close environment of young stars is more complex than the simple models used in the literature so far.

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Dust grain growth in rho-Ophiuchi protoplanetary disks

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We present new ATCA observations at 3.3 mm of 27 young stellar objects in the $\rho-$Oph young cluster. 25 of these sources have been detected. We analyze the sub-millimeter and millimeter SED for a subsample of 17 isolated class II protoplanetary disks and derive constraints on the grain growth and total dust mass in the disk outer regions. All the disks in our sample show a mm slope of the SED which is significantly shallower than the one observed for the ISM at these long wavelengths. This indicates that 1) class II disks in Ophiuchus host grains grown to mm/cm-sizes in their outer regions, 2) formation of mm/cm-sized pebbles is a fast process and 3) a mechanism halting or slowing down the inward radial drift of solid particles is required to explain the data. These findings are consistent with previous results in other star forming regions. We compare the dust properties of this sample with those of a uniformly selected sample in Taurus-Auriga and find no statistical evidence of any difference in terms of grain growth between the two regions. Finally, in our sample the mm slope of the SED is not found to correlate with indicators of grain growth to micron sizes in the surface layers of the inner disk.

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A Cluster of Compact Radio Sources in W40

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We present deep 3.6 cm radio continuum observations of the HII region W40 obtained using the Very Large Array in its A and B configurations. We detect a total of 20 compact radio sources in a region of 4×4 arcmin, with 11 of them concentrated in a band with 30" of extent. We also present JHK photometry of the W40 cluster taken with the

QUIRC instrument on the University of Hawaii 2.2 meter telescope. These data reveal that 15 of the 20 VLA sources have infrared counterparts, and 10 show radio variability with periods less than 20 days. Based on these combined radio and IR data, we propose that 8 of the radio sources are candidate ultracompact HII regions, 7 are likely to be young stellar objects, and 2 may be shocked interstellar gas.

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Spitzer reveals what's behind Orion's Bar

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We present *Spitzer* Space Telescope observations of 11 regions southeast of the Bright Bar in the Orion Nebula, along a radial from the exciting star θ^1 Ori C, extending from 2.6 to 12.1′. Our Cycle 5 programme obtained deep spectra with matching IRS short-high (SH) and long-high (LH) aperture grid patterns. Most previous IR missions observed only the inner few arcmin (the "Huygens" Region). The extreme sensitivity of *Spitzer* in the 10-37 μm spectral range permitted us to measure many lines of interest to much larger distances from θ^1 Ori C. Orion is the benchmark for studies of the interstellar medium, particularly for elemental abundances. *Spitzer* observations provide a unique perspective on the neon and sulfur abundances by virtue of observing the dominant ionization states of Ne (Ne^+, Ne^{++}) and S (S^{++}, S^{3+}) in Orion and H II regions in general. The Ne/H abundance ratio is especially well determined, with a value of $(1.01 \pm 0.08)\times10^{-4}$ or in terms of the conventional expression, 12 + log (Ne/H) = 8.00±0.03.

We obtained corresponding new ground-based spectra at Cerro Tololo Interamerican Observatory (CTIO). These optical data are used to estimate the electron temperature, electron density, optical extinction, and the S^+/S^{++} ionization ratio at each of our *Spitzer* positions. That permits an adjustment for the total gas-phase sulfur abundance because no S^+ line is observed by *Spitzer*. The gas-phase S/H abundance ratio is $(7.68 \pm 0.30) \times 10^{-6}$ or 12 + log (S/H) = 6.89±0.02. The Ne/S abundance ratio may be determined even when the weaker hydrogen line, H(7–6) here, is not measured. The mean value, adjusted for the optical S^+/S^{++} ratio, is Ne/S = 13.0 ± 0.6.

We derive the electron density (N_e) versus distance from θ^1 Ori C for [S III] (*Spitzer*) and [S II] (CTIO). Both distributions are for the most part decreasing with increasing distance. The values for N_e [S II] fall below those of N_e [S III] at a given distance except for the outermost position. This general trend is consistent with the commonly accepted blister model for the Orion Nebula. The natural shape of such a blister is concave with an underlying decrease in density with increasing distance from the source of photoionization.

Our spectra are the deepest ever taken in these outer regions of Orion over the 10-37 μm range. Tracking the changes in ionization structure via the line emission to larger distances provides much more leverage for understanding the far less studied outer regions. A dramatic find is the presence of high-ionization Ne^{++} all the way to the outer optical boundary ∼12′ from θ^1 Ori C. This IR result is robust, whereas the optical evidence from observations of high-ionization species (e.g. O^{++}) at the outer optical boundary suffers uncertainty because of scattering of emission from the much brighter inner Huygens Region. The *Spitzer* spectra are consistent with the Bright Bar being a high-density 'localized escarpment' in the larger Orion Nebula picture. Hard ionizing photons reach most solid angles well SE of the Bright Bar. The so-called Orion foreground 'Veil', seen prominently in projection at our outermost position 12′ from θ^1 Ori C, is likely an H II region – photo-dissociation region (PDR) interface. The *Spitzer* spectra show very strong enhancements of PDR lines – [Si II] 34.8 μm, [Fe II] 26.0 μm, and molecular hydrogen – at the outermost position.

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http://spacescience.arc.nasa.gov/∼rubin/

Recurring millimeter flares as evidence for star-star magnetic reconnection events in the DQ Tau PMS binary system

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Observations of the T Tauri spectroscopic binary DQ Tau in April 2008 captured an unusual flare at 3 mm, which peaked at an observed maximum flux of ∼0.5 Jy (about 27 times the quiescent value). Here we present follow-up millimeter observations that **demonstrate** a periodicity to the phenomenon. While monitoring 3 new periastron encounters, we have detected flares within **17.5** hours (or **4.6**%) of the orbital phase of the first reported flare and constrained the main emitting region to a stellar height of 3.7–6.8 $R_\star$. The recorded activity is consistent with the proposed picture for synchrotron emission initiated by a magnetic reconnection event when the two stellar magnetospheres of the highly eccentric ($e = 0.556$) binary are believed to collide near periastron as the stars approach a minimum separation of 8 $R_\star$ (∼13 $R_\odot$). The similar light curve decay profiles allow us to estimate an average flare duration of 30 hours. Assuming one millimeter flare per orbit, DQ Tau could spend approximately 8% of its 15.8-day orbital period in an elevated flux state. These findings continue to serve as a small caution for millimeter flux points in spectral energy distributions that could contain unrecognized flare contributions. Our analysis of the millimeter emission provides an upper limit of 5% on the linear polarization. We discuss the extent to which a severely entangled magnetic field structure and Faraday rotation effects are likely to reduce the observed polarization fraction. We also predict that, for the current picture, the stellar magnetospheres must be misaligned at a significant angle or, alternatively, that the topologies of the outer magnetospheres are poorly described by a well-ordered dipole inside a radius of 7 $R_\star$. Finally, to investigate whether reorganization of the magnetic field during the interaction affects mass accretion, we also present simultaneous optical (VRI) monitoring of the binary, as an established tracer of accretion activity in this system. We find that an accretion event can occur coincident in both time and duration with the synchrotron fallout of a magnetic reconnection event. While the pulsed accretion mechanism has been attributed previously to the dynamical motions of the stars alone, the similarities between the millimeter and optical light curves evoke the possibility of a causal or co-dependent relationship between the magnetospheric and dynamical processes.

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Trigonometric Parallax of W51 Main/South

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We report measurement of the trigonometric parallax of W51 Main/South using the Very Long Baseline Array (VLBA). We measure a value of 0.185 ± 0.010 mas, corresponding to a distance of $5.41^{+0.31}_{-0.28}$ kpc. W51 Main/South is a well-known massive star-forming region near the tangent point of the Sagittarius spiral arm of the Milky Way. Our distance to W51 yields an estimate of the distance to the Galactic center of $R_0 = 8.3 \pm 0.46$ (statistical) ± 1.0 (systematic) kpc by simple geometry. Combining the parallax and proper motion measurements for W51, we obtained the full-space motion of this massive star forming region. We find W51 is in a nearly circular orbit about the Galactic center. The H_2O masers used for our parallax measurements trace four powerful bipolar outflows within a 0.4 pc size region, some

of which are associated with dusty molecular hot cores and/or hyper- or ultra-compact HII regions.

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A multiwavelength view of the protostellar binary IRAS04325+2402: a case for turbulent fragmentation

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IRAS04325+2402 (herafter IRAS04325) is a complex protostellar system hosting two young stellar objects (AB and C in the following) at a separation of 1250 AU. Here we present new deep Gemini imaging and spectroscopy for the system covering the wavelength regime from 1-12 μm as well as Sub-Millimeter Array interferometry at 870 μm, in combination with Spitzer and literature data. Based on this rich dataset we provide a comprehensive picture of IRAS04325 over scales from a few AU to several parsec. Object AB is a low-mass star with a disk/envelope system and an outflow cavity, which is prominently seen in infrared images. Object C, previously suspected to be a brown dwarf, is likely a very low mass star, with an effective temperature of $\sim$ 3400 K. It features an edge-on disk and an elongated envelope, and shows strong indications for accretion and ejection activity. Both objects are likely to drive parsec-scale molecular outflows. The two objects are embedded in an isolated, dense molecular cloud core. High extinction, lack of X-ray emission, and relatively high bolometric luminosity argue for a very young age below 1 Myr. The disk/outflow systems of AB and C are misaligned by $\sim$ 60 deg against each other and by 80 and 40 deg against the orbital plane of the binary. The system might be a good case for primordial misalignment, as opposed to misalignment caused by dynamical interactions, because the outflow direction is constant and the realignment timescale is likely larger than the system age. This favours turbulent fragmentation, rather than rotational fragmentation, as the formation scenario. We show that the spectral energy distributions and images for the two objects can be reproduced with radiative transfer models for disk/envelope systems. Our analysis provides reassurance in the established paradigm for the structure and early evolution of YSOs, but stresses the importance of developing 3D models with sophisticated dust chemistry.

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Chemistry in Disks. IV. Benchmarking gas-grain chemical models with surface reactions.

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We describe and benchmark two sophisticated chemical models developed by the Heidelberg and Bordeaux astrochemistry groups. The main goal of this study is to elaborate on a few well-described tests for state-of-the-art astrochemical codes covering a range of physical conditions and chemical processes, in particular those aimed at constraining current and future interferometric observations of protoplanetary disks. We considered three physical models: a cold molecular cloud core, a hot core, and an outer region of a T Tauri disk. Our chemical network (for both models) is based on the original gas-phase osu_03_2008 ratefile and includes gas-grain interactions and a set of surface reactions for the H-, O-, C-, S-, and N-bearing molecules. The benchmarking was performed with the increasing complexity of the considered processes: (1) the pure gas-phase chemistry, (2) the gas-phase chemistry with accretion and desorption, and (3) the full gas-grain model with surface reactions. The chemical evolution is modeled within 10^9 years using atomic initial abundances with heavily depleted metals and hydrogen in its molecular form. The time-dependent abundances calculated with the two chemical models are essentially the same for all considered physical cases and for all species, including the most complex polyatomic ions and organic molecules. This result, however, required a lot of effort to make all necessary details consistent through the model runs, e.g., definition of the gas particle density, density of grain surface sites, or the strength and shape of the UV radiation field. The reference models and the benchmark setup, along with the two chemical codes and resulting time-dependent abundances are made publicly available on the internet. This will facilitate and ease the development of other astrochemical models and provide nonspecialists with a detailed description of the model ingredients and requirements to analyze the cosmic chemistry as studied, e.g., by (sub-) millimeter observations of molecular lines.

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Spitzer Space Telescope observations of the Carina Nebula: The steady march of feedback-driven star formation

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We report the first results of imaging the Carina Nebula (NGC 3372) with the Infrared Array Camera (IRAC) onboard the *Spitzer Space Telescope*, providing a photometry catalog of over 44,000 point sources as well as a catalog of over 900 candidate young stellar objects (YSOs) based on fits to their spectral energy distributions (SEDs). We discuss several aspects of the extended emission, including the structure of dozens of dust pillars that result when a clumpy molecular cloud is shredded by feedback from massive stars. There are surprisingly few of the "extended green objects" (EGOs) that are normally taken as signposts of outflow activity in *Spitzer* data, and not one of the dozens of Herbig-Haro jets detected optically are seen as EGOs. EGOs are apparently poor tracers of outflow activity in strongly irradiated environments, due to the effects of massive star feedback. A population of "extended red objects" tends to be found around late O-type and early B-type stars, some with clear bow-shock morphology. These are dusty shocks where stellar winds collide with photoevaporative flows off nearby clouds. Finally, the relative distributions of O-type stars, small star clusters, and sub-clusters of YSOs as compared to the dust pillars shows that while some YSOs are located within dust pillars, many more stars and YSOs reside just outside pillar heads. We suggest that pillars are transient phenomena, part of a continuous outwardly propagating wave of star formation driven by feedback from massive stars. As the pillars are destroyed, they leave newly formed stars in their wake, and these are then subsumed into the young

OB association. The YSOs are found predominantly in the cavity between pillars and massive stars, arguing that their formation was in fact triggered. Altogether, the current generation of YSOs shows no strong deviation from a normal initial mass function (IMF). The number of YSOs is consistent with a roughly constant star-formation rate over the past ∼3 Myr, implying that propagating star formation in pillars constitutes an important mechanism to construct unbound OB associations. These accelerated pillars may give birth to massive O-type stars that, after several Myr, could appear to have formed in isolation.

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Stellar-Mass-Dependent Disk Structure in Coeval Planet-Forming Disks

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Previous studies suggest that the planet-forming disks around very-low-mass stars/brown dwarfs may be flatter than those around more massive stars, in contrast to model predictions of larger scale heights for gas-disks around lower-mass stars. We conducted a statistically robust study to determine whether there is evidence for stellar-mass-dependent disk structure in planet-forming disks. We find a statistically significant difference in the Spitzer/IRAC color distributions of disks around very-low-mass and low-mass stars all belonging to the same star-forming region, the Chamaeleon I star-forming region. We show that self consistently calculated disk models cannot fit the median spectral energy distributions (SEDs) of the two groups. These SEDs can be only explained by flatter disk models, consistent with the effect of dust settling in disks. We find that relative to the disk structure predicted for flared disks the required reduction in disk scale height is anti-correlated with the stellar mass, i.e. disks around lower-mass stars are flatter. Our results show that the initial and boundary conditions of planet formation are stellar-mass-dependent, an important finding that must be considered in planet formation models.

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Debris discs in binaries: a numerical study

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Debris disc analysis and modelling provide crucial information about the structure and the processes at play in extrasolar planetary systems. In binary systems, this issue is more complex because the disc should in addition respond to the companion star's perturbations. We explore the dynamical evolution of a collisionally active debris disc for different initial parent body populations, diverse binary configurations and optical depths. We focus on the radial extent and size distribution of the disc at a stationary state. We numerically follow the evolution of 10^5 massless small grains, initially produced from a circumprimary disc of parent bodies following a size distribution in $dN \propto s^{-3.5}$ds . Grains are submitted to both stars' gravity as well as radiation pressure. In addition, particles are assigned an empirically derived collisional lifetime. For all the binary configurations the disc extends far beyond the critical semimajor axis a_{crit} for orbital stability. This is due to the steady production of small grains, placed on eccentric orbits reaching beyond a_{crit} by radiation pressure. The amount of matter beyond acrit depends on the balance between collisional production and dynamical removal rates: it increases for more massive discs as well as for eccentric binaries. Another important effect is that, in the dynamically stable region, the disc is depleted from its smallest grains. Both results could lead to observable signatures. We have shown that a companion star can never fully

truncate a collisionally active disc. For eccentric companions, grains in the unstable regions can significantly contribute to the thermal emission in the mid-IR. Discs with sharp outer edges, especially bright ones such as HR4796A, are probably shaped by other mechanisms.

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The Inner Envelope and Disk of L1527 Revealed: Gemini L'-band Scattered Light Imaging

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We present high-resolution L′-band imaging of the inner scattered light structure of Class 0 protostar L1527 IRS (IRAS 04368+2557) taken with the Gemini North telescope. The central point-source like feature seen in *Spitzer Space Telescope* IRAC images is resolved in the Gemini image into a compact bipolar structure with a narrow dark lane in the center. Two scattered light lobes are extended ∼1.8″ (200 AU) perpendicular to the direction of the outflow and ∼2.5″ (350 AU) along the outflow axis; the narrow dark lane between the scattered light lobes is ∼ 0.45″ (60 AU) thick. The observations are consistent with our initial modeling of a bright inner cavity separated by a dark lane due to extinction along the line of sight of the central protostar by the disk (Tobin et al. 2008). The bright, compact scattered light might be due to complex inner structure generated by the outflow, as suggested in our first paper, or it may more likely be the upper layers of the disk forming from infalling matter.

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http://www.astro.lsa.umich.edu/∼jjtobin/L1527-Gemini.pdf

A wide-angle outflow with the simultaneous presence of a high-velocity jet in the high-mass Cepheus A HW2 system

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We present five epochs of VLBI water maser observations around the massive protostar Cepheus A HW2 with 0.4 mas (0.3 AU) resolution. The main goal of these observations was to follow the evolution of the remarkable water maser linear/arcuate structures found in earlier VLBI observations. Comparing the data of our new epochs of observation with those observed five years before, we find that at "large" scales of $> 1''$ (700 AU) the main regions of maser emission persist, implying that both the surrounding medium and the exciting sources of the masers have been relatively stable during that time span. However, at smaller scales of $< 0.1''$ (70 AU) we see large changes in the maser structures, particularly in the expanding arcuate structures R4 and R5. R4 traces a nearly elliptical patchy ring of ∼ 70 mas size (50 AU) with expanding motions of ∼ 5 mas yr^{-1} (15 km s^{-1}), consistent with previous results of Gallimore and collaborators. This structure is probably driven by the wind of a still unidentified YSO located at the centre of the ring ($\sim 0.18''$ south of HW2). On the other hand, the R5 expanding bubble structure (driven by the wind of a previously identified YSO located $\sim 0.6''$ south of HW2) is currently dissipating in the circumstellar medium and losing its previous degree of symmetry, indicating a very short-lived event. In addition, our results reveal, at scales of $\sim 1''$ (700 AU), the simultaneous presence of a relatively slow ($\sim$ 10-70 km s^{-1}) wide-angle outflow (opening angle of $\sim 102°$), traced by the masers, and the fast ($\sim$ 500 km s^{-1}) highly collimated radio jet associated with HW2 (opening angle of $\sim 18°$), previously observed with the VLA. This simultaneous presence of a wide-angle outflow and a highly collimated jet associated with a massive protostar is similar to what is found in some low-mass YSOs. There are indications that the primary wind(s) from HW2 could be rotating. The implications of these results in the study of the formation of high-mass stars are discussed.

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[CII] observations of H_2 molecular layers in transition clouds

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We present the first results on the diffuse transition clouds observed in [CII] line emission at 158 μm(1.9 THz) towards Galactic longitudes near 340° (5 LOSs) & 20° (11 LOSs) as part of the HIFI tests and **GOT C+** survey. Out of the total 146 [CII] velocity components detected by profile fitting we identify 53 as diffuse molecular clouds with associated ^{12}CO emission but without ^{13}CO emission and characterized by $A_V < 5$ mag. We estimate the fraction of the [CII] emission in the diffuse HI layer in each cloud and then determine the [CII] emitted from the molecular layers in the cloud. We show that the excess [CII] intensities detected in a few clouds is indicative of a thick H_2 layer around the CO core. The wide range of clouds in our sample with thin to thick H_2 layers suggests that these are at various evolutionary states characterized by the formation of H_2 and CO layers from HI and C^+, respectively. In about 30% of the clouds the H_2 column densities ("dark gas") traced by the [CII] is 50% or more than that traced by ^{12}CO emission. On the average $\sim$ 25% of the total H_2 in these clouds is in an H_2 layer which is not traced by CO. We use the HI, [CII], and ^{12}CO intensities in each cloud along with simple chemical models to obtain constraints on the FUV fields and cosmic ray ionization rates.

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Simulations of Winds of Weak-Lined T Tauri Stars. II.: The Effects of a Tilted Magnetosphere and Planetary Interactions

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Based on our previous work, we investigate here the effects on the wind and magnetospheric structures of weak-lined T Tauri stars due to a misalignment between the axis of rotation of the star and its magnetic dipole moment vector. In such configuration, the system loses the axisymmetry presented in the aligned case, requiring a fully three-dimensional approach. We perform three-dimensional numerical magnetohydrodynamic simulations of stellar winds and study the effects caused by different model parameters, namely the misalignment angle θ_t, the stellar period of rotation, the plasma-β, and the heating index γ. Our simulations take into account the interplay between the wind and the stellar magnetic field during the time evolution. The system reaches a periodic behavior with the same rotational period

of the star. We show that the magnetic field lines present an oscillatory pattern. Furthermore, we obtain that by increasing θ_t, the wind velocity increases, especially in the case of strong magnetic field and relatively rapid stellar rotation. Our three-dimensional, time-dependent wind models allow us to study the interaction of a magnetized wind with a magnetized extra-solar planet. Such interaction gives rise to reconnection, generating electrons that propagate along the planet's magnetic field lines and produce electron cyclotron radiation at radio wavelengths. The power released in the interaction depends on the planet's magnetic field intensity, its orbital radius, and on the stellar wind local characteristics. We find that a close-in Jupiter-like planet orbiting at 0.05 AU presents a radio power that is ~ 5 orders of magnitude larger than the one observed in Jupiter, which suggests that the stellar wind from a young star has the potential to generate strong planetary radio emission that could be detected in the near future with LOFAR. This radio power varies according to the phase of rotation of the star. For three selected simulations, we find a variation of the radio power of a factor 1.3 to 3.7, depending on θ_t. Moreover, we extend the investigation done in Vidotto et al. and analyze whether winds from misaligned stellar magnetospheres could cause a significant effect on planetary migration. Compared to the aligned case, we show that the time-scale τ_w for an appreciable radial motion of the planet is shorter for larger misalignment angles. While for the aligned case $\tau_w \simeq 100$ Myr, for a stellar magnetosphere tilted by $\theta_t = 30^o$, τ_w ranges from ~ 40 to 70 Myr for a planet located at a radius of 0.05 AU. Further reduction on τ_w might occur for even larger misalignment angles and/or different wind parameters.

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http://arxiv.org/abs/1007.3874

The 2008 Outburst in the Young Stellar System Z CMa: The First Detection of Twin Jets

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The Z CMa binary is understood to undergo both FU Orionis (FUOR) and EX Orionis (EXOR) type outbursts. While the SE component has been spectroscopically classified as an FUOR, the NW component, a Herbig Be star, is the source of the EXOR outbursts. The system has been identified as the the source of a large outflow; however, previous studies have failed to identify the driver. Here, we present adaptive optics assisted [FeII] spectro-images which reveal for the first time the presence of two small-scale jets. Observations made using OSIRIS at the Keck Observatory show the Herbig Be star to be the source of the parsec-scale outflow, which within 2 arcseconds of the source shows signs of wiggling and the FUOR to be driving a 0.4 arcsecond jet. The wiggling of the Herbig Be star's jet is evidence for an additional companion which could in fact be generating the EXOR outbursts, the last of which began in 2008. Indeed, the dynamical timescale of the wiggling corresponds to a timescale of 4-8 years which is in agreement with the timescale of these outbursts. The spectro-images also show a bow-shock shaped feature and possible associated knots. The origin of this structure is as of yet unclear. Finally, interesting low velocity structure is also observed. One possibility is that it originates in a wide-angle outflow launched from a circumbinary disk.

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Herschel-HIFI observations of high-J CO lines in the NGC 1333 low-mass star-forming region

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Herschel-HIFI observations of high-J lines (up to J_u=10) of ^{12}CO, ^{13}CO and C^{18}O are presented toward three deeply embedded low-mass protostars, NGC 1333 IRAS 2A, IRAS 4A, and IRAS 4B, obtained as part of the *Water In Star-forming regions with Herschel* (WISH) key program. The spectrally-resolved HIFI data are complemented by ground-based observations of lower-J CO and isotopologue lines. The ^{12}CO 10–9 profiles are dominated by broad (FWHM 25–30 km s^{-1}) emission. Radiative transfer models are used to constrain the temperature of this shocked gas to 100–200 K. Several CO and ^{13}CO line profiles also reveal a medium-broad component (FWHM 5–10 km s^{-1}), seen prominently in H_2O lines. Column densities for both components are presented, providing a reference for determining abundances of other molecules in the same gas. The narrow C^{18}O 9–8 lines probe the warmer part of the quiescent envelope. Their intensities require a jump in the CO abundance at an evaporation temperature around 25 K, thus providing new direct evidence for a CO ice evaporation zone around low-mass protostars.

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Gas emission from debris disks around F and A stars

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Gas has been detected in a number of debris disk systems. This gas may have arisen from grain sublimation or grain photodesorption. It interacts with the surrounding dust grains through a number of charge and heat exchanges. Studying the chemical composition and physical state of this gas can therefore reveal much about the dust component in these debris disks. We have produced a new code, ontario, to address gas emission from dusty gas-poor disks around A–F stars. This code computes the gas ionization and thermal balance self-consistently, with particular care taken of heating/cooling mechanisms. Line emission spectra are then produced for each species (up to zinc) by statistical equilibrium calculations of the atomic/ionic energy levels. For parameters that resemble the observed β Pictoris gas disk, we find that the gas is primarily heated by photoelectric emission from dust grains, and primarily cooled through the C II 157.7 μm line emission. The gas can be heated to a temperature that is warmer than that of the dust and may in some cases reach temperature for thermal escape. The dominant cooling line, C II 157.7 μm, should be detectable by Herschel in these disks, while the O I 63.2 μm line will be too faint. We also study the dependence of the cooling line fluxes on a variety of disk parameters, in light of the much improved sensitivity to thermal line emission in the mid/far infrared and at sub-millimeter wavelengths provided by, in particular, Herschel, SOFIA and ALMA. These new instruments will yield much new information about dusty debris disks.

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The magnetic fields of forming solar-like stars

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Magnetic fields play a crucial role at all stages of the formation of low mass stars and planetary systems. In the final stages, in particular, they control the kinematics of in-falling gas from circumstellar discs, and the launching and collimation of spectacular outflows. The magnetic coupling with the disc is thought to influence the rotational evolution of the star, while magnetised stellar winds control the braking of more evolved stars and may influence the migration of planets. Magnetic reconnection events trigger energetic flares which irradiate circumstellar discs with high energy particles that influence the disc chemistry and set the initial conditions for planet formation. However, it is only in the past few years that the current generation of optical spectropolarimeters have allowed the magnetic fields of forming solar-like stars to be probed in unprecedented detail. In order to do justice to the recent extensive observational programs new theoretical models are being developed that incorporate magnetic fields with an observed degree of complexity. In this review we draw together disparate results from the classical electromagnetism, molecular physics/chemistry, and the geophysics literature, and demonstrate how they can be adapted to construct models of the large scale magnetospheres of stars and planets. We conclude by examining how the incorporation of multipolar magnetic fields into new theoretical models will drive future progress in the field through the elucidation of several observational conundrums.

Accepted by Reports on Progress in Physics

http://arxiv.org/abs/1008.1883

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals), *Abstracts of recently accepted major reviews* (not standard conference contributions), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star and planet formation and early solar system community), *New Jobs* (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and *Short Announcements* (where you can inform or request information from the community).

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each issue of the newsletter. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm
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The Star Formation Newsletter is available on the World Wide Web at http://www.ifa.hawaii.edu/users/reipurth/newsletter.htm.

Postdoctoral position on stellar cluster dynamics in Grenoble

Applications are invited for a postdoctoral position at the Laboratoire d'Astrophysique de Grenoble in the framework of DESC (Dynamical Evolution of Stellar Clusters), a research project funded by the French National Research Agency (ANR).

The Laboratoire d'Astrophysique de Grenoble (LAOG) carries out observational and theoretical research in various field of astrophysics including the chemistry of interstellar medium, star and planet formation, and high energy phenomena. The LAOG is also involved in the technical development of major high angular resolution instruments for the VLT, VLTI and E-ELT.

The proposed research project will focus on numerical investigations of the early dynamical evolution of open clusters, with the aim to constrain the stellar cluster formation process(es). A special emphasis will be given to the comparison between simulations and observations, in the context of the preparation to the astrometric space mission Gaia. The successful candidate will be working in the star formation group in LAOG which has a vast experience in young cluster observations, including large scale photometric surveys and spectroscopic studies; and in collaboration with the Galaxy team in Strasbourg, which has strong expertise in gravitational dynamics and N-body numerical simulations.

Applicants must have a PhD and should have experience in N-body simulations or radiative transfer. Background in star formation theories or in stellar cluster observational studies will be an asset. The position is for two to three years, starting preferentially before the end of 2010. The gross yearly salary will be 32 KEuro, plus 1 KEuro for relocation expenses.

Applications should include a curriculum vitae, a list of publications and a statement of research interests and experience. The applicants should also arrange for two letters of recommendation to be sent independently. All materials should be directed to Estelle Moraux by October 15, 2010, either electronically to emoraux at obs.ujf-grenoble.fr or by mail at the following address: Estelle Moraux, Laboratoire d'Astrophysique de Grenoble, Universite Joseph Fourier, BP 53, 38041 Grenoble Cedex 9, France

Any enquiries should be adressed to Estelle Moraux (emoraux at obs.ujf-grenoble.fr). Additional informations on LAOG can also be obtained from http://www-laog.obs.ujf-grenoble.fr/

Postdoctoral Research Associate in Theoretical/Computational Star Formation

Applications are invited for a postdoctoral fellowship in the Department of Physics and Astronomy at The University of Western Ontario to study star and planet formation. This position is advertised in conjunction with the CITA National Fellowship program. The successful candidate will work with Prof. Shantanu Basu to perform numerical simulations and theoretical modeling of the formation and evolution of star-disk systems. Candidates with suitable experience in these areas will be given special consideration. Current and future projects in the group may include the study of non-ideal MHD effects in fragmentation, collapse, and disk evolution, the study of the formation of multiple systems, including possibly giant planets, and the analysis of observations in order to make useful comparisons with theoretical models.

The Astronomy Group at Western has recently expanded, with eleven faculty members focusing on AGN's, nearby galaxies, planetary science, star formation, and stellar astronomy. A postdoctoral fellow can expect to have lively interactions with faculty, several other pdfs, and a growing group of graduate students. Researchers at Western have access to the computational resources of SHARCNET, a multi-institution regional supercomputer consortium.

The position is for two years, with possible renewal for a third year subject to performance and availability of funds. Interested individuals should send a curriculum vita and a statement of research interests, and arrange for three letters of reference to be sent to Jodi Guthrie (jodi@uwo.ca). Complete (preferably electronic) applications must be received by October 22, 2010. The University of Western Ontario is committed to employment equity.

ALMA: Extending the Limits of Astrophysical Spectroscopy

Pre-registration is now open for a major science conference entitled "ALMA: Extending the Limits of Astrophysical Spectroscopy", in Victoria, BC, Canada, 15-17 January 2011, hosted by the National Radio Astronomy Observatory (NRAO) in cooperation with the National Research Council of Canada. The capabilities of new Atacama Large Millimeter/submillimeter Array (ALMA) instrumentation will be highlighted at this meeting via invited and contributed science talks in astronomy, astrophysics, and astrochemistry.

Specific focus areas for this conference will include:

- The Atomic Universe: Atomic Spectra as Probes of Cool Gas (Invited speaker David Neufeld (JHU))

- The Molecular Universe: Dense Star-forming Gas (Invited speakers Ted Bergin (UMichigan) & Christine Wilson (McMasterU))

- Isotopic Variety in Interstellar Medium (Invited speaker Darek Lis (CalTech))

- Our Molecular Origins: Prebiotic Molecules (Invited speaker Stefanie Milam (GSFC))

Attendance will be limited to approximately 100 participants. Please see the conference web site

http://almatelescope.ca/Spectroscopy2011/

for further information and pre-registration.

Transport Processes and Accretion in YSOs

Schloss Ringberg, 7-11 February 2011

http://accretion2011.mpe.mpg.de/index.php

The goal of this workshop is to establish what is known about how accretion onto young stars works, identify the most important problems that remain, and discuss future observational and modelling efforts that should be developed to begin to solve these problems. The workshop will include dedicated time for discussion. Presentations and discussion formation will be designed to highlight both recent developments within the field and the uncertainties in underlying assumptions that should be addressed.

Registration will open on 1 September 2010 and close on 15 October 2010. The workshop is strictly limited to 60 participants, of whom 40 can stay at the Castle and 20 can stay in a nearby town. Schloss Ringberg overlooks Tegernsee in the Bavarian Alps, about an hour outside of Munich.

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