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Abstracts of recently accepted papers

Long Term Evolution of Close Planets Including the Effects of Secular Interactions

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This paper studies the long term evolution of planetary systems containing short-period planets, including the effects of tidal circularization, secular excitation of eccentricity by companion planets, and stellar damping. For planetary systems subject to all of these effects, analytic solutions (or approximations) are presented for the time evolution of the semi-major axes and eccentricities. Secular interactions enhance the inward migration and accretion of hot Jupiters, while general relativity tends to act in opposition by reducing the effectiveness of the secular perturbations. The analytic solutions presented herein allow us understand these effects over a wide range of parameter space and to isolate the effects of general relativity in these planetary systems.

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Effects of Secular Interactions in Extrasolar Planetary Systems

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This paper studies the effects of dynamical interactions among the planets in observed extrasolar planetary systems, including hypothetical additional bodies, with a focus on secular perturbations. These interactions cause the eccentricities of the planets to explore a distribution of values over time scales that are long compared to observational time baselines, but short compared to the age of the systems. The same formalism determines the eccentricity forcing of hypothetical test bodies (terrestrial planets) in these systems and we find which systems allow for potentially habitable planets. Such planets would be driven to nonzero orbital eccentricity and we derive the distribution of stellar flux experienced by the planets over the course of their orbits. The general relativistic corrections to secular interaction theory are included in the analysis and such effects are important in systems with close planets ($\sim$4 day orbits). Some extrasolar planetary systems (e.g., Upsilon Andromedae) can be used as a test of general relativity, whereas in other systems, general relativity can be used to constrain the system parameters (e.g., $\sin i \geq 0.93$ for HD160691). For the case of hot Jupiters, we discuss how the absence of observed eccentricity implies the absence of companion planets.

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The Thermal Structure of Gas in Prestellar Cores: A Case Study of Barnard 68

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We present a direct comparison of a chemical/physical model to multitransitional observations of $C^{18}O$ and ^{13}CO toward the Barnard 68 prestellar core. These observations provide a sensitive test for models of low UV field photodissociation regions and offer the best constraint on the gas temperature of a prestellar core. We find that the gas temperature of this object is surprisingly low (78 K), and significantly below the dust temperature, in the outer layers ($A_V < 5$ mag) that are traced by $C^{18}O$ and ^{13}CO emission. As shown previously, the inner layers ($A_V > 5$ mag) exhibit significant freezeout of CO onto grain surfaces. Because the dust and gas are not fully coupled, depletion of key coolants in the densest layers raises the core (gas) temperature, but only by 1 K. The gas temperature in layers not traced by $C^{18}O$ and ^{13}CO emission can be probed by NH_3 emission, with a previously estimated temperature of $\sim$ 10-11 K. To reach these temperatures in the inner core requires an order of magnitude reduction in the gas to dust coupling rate. This potentially argues for a lack of small grains in the densest gas, presumably due to grain coagulation.

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A Photoionized Herbig-Haro Object in the Orion Nebula

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The spectra of Herbig-Haro objects are usually characteristic of ionization and excitation in shock-heated gas, whether an internal shock in an unsteady outflow or a bow shock interface with the interstellar medium. We examine the easternmost shock – the leading optically visible shock – of a Herbig-Haro outflow (HH 529) seen projected on the face of the Orion Nebula, using deep optical echelle spectroscopy, showing that the spectrum of this gas is consistent with photoionization by θ_1 Ori C. By modeling the emission lines, we determine a gas-phase abundance of Fe that is consistent with the depleted (relative to solar) abundance found in the Orion nebulaevidence for the presence of dust in the nebula and therefore in the Herbig-Haro outflow. The spectrum also allows for the calculation of temperature fluctuations, t^2, in the nebula and the shock. These fluctuations have been used to explain discrepancies between abundances obtained from recombination lines versus those obtained from collisionally excited lines, although to date there has not been a robust theory for how such large fluctuations ($t^2 > 0.02$) can be.

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The motion of wind-driven shells

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We present a method for solving problems in which a stellar wind interacts with the surrounding environment through the production of a 'double radiative shock' structure. This condition is generally met in problems involving winds

ejected from young stars. We describe a method that can be applied to problems of winds with arbitrary time and angular dependence, interacting with a stationary environment with an arbitrary density distribution. We apply the method to the interaction of: a steady wind (with an instantaneous 'turning-on') with a power-law environmental density stratification, a 'wind plus jet' ejection with a toroidal environmental density stratification, and to the interaction of an isotropic wind with a clumpy environment. These three examples illustrate the wide range of possible applications of the proposed method. We also show a comparison between some of our thin-shell solutions and three-dimensional isothermal gasdynamic simulations of the flows. These comparisons are used as an evaluation of the applicability of our thin-shell solutions to the real flows.

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Methods for analysing structure in molecular clouds

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We have previously reported a dimensionless measure, $\mathcal{Q}$, which can both quantify, and distinguish between, the extent to which a star cluster is centrally concentrated, and the extent to which it contains small-scale subclusters. $\mathcal{Q}$ is the ratio of the normalized correlation length, $\overline{s}$, (i.e. the mean projected separation between stars, divided by the overall radius of the cluster), to the mean length, $\overline{\ell}$, of the segments of a minimal spanning tree (MST) joining all star positions: $\mathcal{Q} = \overline{s}/\overline{\ell}$.

In this paper, we attempt to adapt the correlation-length method to the characterization of gas clouds, with a view to comparing directly the structures of gas clouds and star clusters. We also compare the results of the correlation-length method with fractal dimensions estimated using the more familiar perimeter-area method whereby the lengths of closed contours are plotted against the areas they enclose, on a log-log plot.

We find that the normalized correlation length, when modified to deal with pixellated grey-scale data, is a robust indicator of either central concentration or fractal subclustering of gas clouds, but cannot distinguish between the two types of structure. It is, however, extremely reliable, easy to implement and works accurately at all scales and over all dynamic ranges, even with poorly sampled data. It implicitly incorporates edge effects, so all the data in the complete cloud are used, and it therefore provides a useful method for comparing the structures of molecular clouds and star clusters.

The normalized correlation length produces comparable results to the perimeter-area method when used on molecular cloud data. However, the perimeter-area method is unable to distinguish the degree of clustering in three-dimensional objects with fractal dimensions greater than 2.0. It also suffers from measurement noise and lack of objectivity, particularly if only a few contours are selected for analysis. It cannot be used to compare clouds with star clusters.

It is not found possible to construct an MST algorithm which works reliably for grey-scale data and is immune to scaling problems. The previously reported parameter is therefore not useful when considering gas clouds.

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Millimeter Imaging of the HH 270 Protostellar Core and Outflow

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The HH 270 region was observed in the $C^{18}O$ and the ^{13}CO $J = 1 \rightarrow 0$ lines with angular resolutions ranging from $3''$ to $10''$. The dense molecular core containing the centimeter continuum source VLA 1 has a mass of $\sim$1.6 $M_\odot$. As the ^{13}CO image shows that the dense core is elongated in the direction perpendicular to the outflow axis, the core may be flattened and viewed nearly edge-on. The ^{13}CO spectrum shows a blue-skewed line profile when the imaging is done with a high resolution, suggesting that the infall motion becomes kinematically important in a small scale, within $\sim$2000 AU from the center. The molecular outflow does not show a large line width, and the outflow axis may

be close to the plane of the sky. Archival near-IR images reveal that there is a nebulosity associated with VLA 1 and that VLA 1 and HH 270 IRS are separate objects. Comparison between the near-IR and optical images with an accurate positional alignment shows that VLA 1 is the driving source of the HH 270 flow. If HH 270 IRS is not a background star, the HH 270 core may be containing a binary system with inhomogeneous spectral classes: VLA 1 may be a Class 0 protostar, and HH 270 IRS may be a young stellar object with a hotter spectral energy distribution.

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G76.188+0.098: a newly born massive binary star

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Context: We present observations of G76.188+0.098, an object classified in the literature as a ultracompact HII region (UCHIIR) based on its far-infrared and radio continuum characteristics.
Aims: To investigate the nature of this object on the basis of the combination of radio observations existing in the literature and the new observations in the near-infrared presented here, with particular attention to the direct detection of the central ionizing source.
Methods: Near-infrared narrow-band imaging and low resolution spectroscopy in the 2μm region.
Results: The new observations clearly reveal the central source, which turns out to be a resolved binary system obscured by $A_K \simeq 4.4$ mag. A general agreement is found between the morphology of the region as outlined by narrow-band, near-infrared imaging, and existing VLA radio continuum maps. Indirect evidence based on the low HeI (2.058 μm) / Brγ intensity ratio of the compact nebula suggests that the binary system is composed of two stars with spectral types O9 and B0 at a distance of ~ 2.4 kpc, somewhat closer to the Sun than commonly assumed in the literature.
Conclusions: The size of the central cavity of the compact nebula, the low electron densities derived from radio continuum measurements, and the moderate extinction towards the central source by UCHIIR standards suggest that G76.188+0.098 is a very young massive binary observed near the end of the embedded, ultracompact phase, adding one example to the rare cases in which the central source of a ultracompact HII region is detected.

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http://www.eso.org/~fcomeron/g76.pdf

A multi-wavelength census of star formation activity in the young embedded cluster around Serpens/G3-G6

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Aims. The aim is to characterize the star formation activity in the poorly studied embedded cluster Serpens/G3-G6, located about 45' (3 pc) to the south of the Serpens Cloud Core, and to determine the luminosity and mass functions of its population of Young Stellar Objects (YSOs). Methods. Multi-wavelength broad band photometry was obtained to sample the near and mid-IR Spectral Energy Distributions in order to separate YSOs from field stars and classify the YSO evolutionary stage. ISOCAM mapping in the two filters LW2 (5-8.5 μm) and LW3 (12-18 μm) of a 19' x 16' field was combined with JHK$_S$ data from 2MASS, K$_S$ data from Arnica/NOT, and L' data from SIRCA/NOT. Continuum emission at 1.3 mm (IRAM) and 3.6 cm (VLA) was mapped to study the cloud structure and the coldest/youngest sources. Deep narrow band imaging at the 2.12 μm S(1) line of H_2 from NOTCam/NOT was obtained to search for signs of bipolar outflows. Results. We have strong evidence for a stellar popultion of 31 Class II sources, 5 flat-spectrum sources, 5 Class I sources and two Class 0 sources. Our method does not sample the Class III sources. The cloud is composed of two main dense clumps aligned along a ridge over ~ 0.5 pc plus a starless core coinciding with absorption features seen in the ISOCAM maps. We find two S-shaped bipolar collimated flows embedded in the NE clump, and propose the two driving sources to be a Class 0 candidate (MMS3) and a double Class I (MMS2). For the Class II population we find a best age of ~ 2 Myr and compatibility with recent Initial Mass Functions (IMFs) by comparing the observed Class II luminosity function (LF) – which is complete to 0.08 $L_\odot$ – to various model LFs with different star formation scenarios and input IMFs.

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http://www.not.iac.es/~amanda/papers/papers.html

The abundances of nitrogen–containing molecules during pre–protostellar collapse

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We have studied the chemistry of nitrogen–bearing species during the initial stages of protostellar collapse, with a view to explaining the observed longevity of N_2H^+ and NH_3 and the high levels of deuteration of these species. We followed the chemical evolution of a medium comprising gas and dust as it underwent free–fall gravitational collapse. Chemical processes which determine the relative populations of the nuclear spin states of molecules and molecular ions were included explicitly, as were reactions which lead ultimately to the deuteration of the nitrogen–containing species N_2H^+ and NH_3. The freeze–out of 'heavy' molecules onto grains was taken into account. We found that the timescale required for the nitrogen–containing species to attain their steady–state values was much larger than the free–fall time and even comparable with the probable lifetime of the precursor molecular cloud. However, it transpires that the chemical evolution of the gas during gravitational collapse is insensitive to its initial composition. If we suppose that the grain–sticking probabilities of atomic nitrogen and oxygen are both *less than unity* ($S < 0.3$), we find that the observed differential freeze–out of nitrogen- and carbon–bearing species can be reproduced by the model of free–fall collapse when a sufficiently large grain radius ($a_g \sim 0.5\mu m$) is adopted. Furthermore, the results of our collapse model are consistent with the high levels of deuteration of N_2H^+ and NH_3 which have been observed in L 1544 for example, providing that $0.5 < a_g < 1.0\mu m$. We note that the ortho:para H_2D^+ ratio, and fractional abundance of ortho-H_2D^+ (which is the observed form of H_2D^+), should be largest where ND_3 is most abundant.

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Supersonic turbulence in shock-bound interaction zones I: symmetric settings

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Colliding hypersonic flows play a decisive role in many astrophysical objects. They contribute, for example, to molecular cloud structure, the X-ray emission of O-stars, differentiation of galactic sheets, the appearance of wind-driven structures, or, possibly, the prompt emission of γ-ray bursts. Our intention is the thorough investigation of the turbulent interaction zone of such flows, the cold dense layer (CDL). In this paper, we focus on the idealized model of a 2D plane parallel isothermal slab and on symmetric settings, where both flows have equal parameters. We performed a set of high-resolution simulations with upwind Mach numbers, $5 < M_{\rm u} < 90$.

We find that the CDL is irregularly shaped and has a patchy and filamentary interior. The size of these structures increases with $\ell_{\rm cdl}$, the extension of the CDL. On average, but not at each moment, the solution is about self-similar

and depends only on M_u. We give the corresponding analytical expressions, with numerical constants derived from the simulation results. In particular, we find the root mean square Mach number to scale as $M_{rms} \approx 0.2M_u$. Independent of M_u is the mean density, $\rho_m \approx 30\rho_u$. The fraction f_{eff} of the upwind kinetic energy that survives shock passage scales as $f_{eff} = 1 - M_{rms}^{-0.6}$. This dependence persists if the upwind flow parameters differ from one side to the other of the CDL, indicating that the turbulence within the CDL and its driving are mutually coupled. In the same direction points the finding that the auto-correlation length of the confining shocks and the characteristic length scale of the turbulence within the CDL are proportional.

In summary, larger upstream Mach numbers lead to a faster expanding CDL with more strongly inclined confining interfaces relative to the upstream flows, more efficient driving, and finer interior structure relative to the extension of the CDL.

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Global MHD simulations of stratified and turbulent protoplanetary discs. I. Model properties

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We present the results of global 3-D MHD simulations of stratified and turbulent protoplanetary disc models. The aim of this work is to develop thin disc models capable of sustaining turbulence for long run times, which can be used for on–going studies of planet formation in turbulent discs. The results are obtained using two codes written in spherical coordinates: GLOBAL and NIRVANA. Both are time–explicit and use finite differences along with the Constrained Transport algorithm to evolve the equations of MHD. In the presence of a weak toroidal magnetic field, a thin protoplanetary disc in hydrostatic equilibrium is destabilised by the magnetorotational instability (MRI). When the resolution is large enough (~ 25 vertical grid cells per scale height), the entire disc settles into a turbulent quasi steady–state after about 300 orbits. Angular momentum is transported outward such that the standard α parameter is roughly $4-6\times10^{-3}$. We find that the initial toroidal flux is expelled from the disc midplane and that the disc behaves essentially as a quasi–zero net flux disc for the remainder of the simulation. As in previous studies, the disc develops a dual structure composed of an MRI–driven turbulent core around its midplane, and a magnetised corona stable to the MRI near its surface. By varying disc parameters and boundary conditions, we show that these basic properties of the models are robust. The high resolution disc models we present in this paper achieve a quasi–steady state and sustain turbulence for hundreds of orbits. As such, they are ideally suited to the study of outstanding problems in planet formation such as disc–planet interactions and dust dynamics.

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The Asymmetric Thermal Emission of the Protoplanetary Disk Surrounding HD 142527 Seen by Subaru/COMICS

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Mid-infrared (MIR) images of the Herbig Ae star HD 142527 were obtained at 18.8 and 24.5μm with the Subaru/COMICS. Bright extended arclike emission (outer disk) is recognized at r = 0.″85 together with a strong central source (inner disk) and a gap around r = 0.″6 in both images. The thermal emission on the eastern side is much brighter than that on the western side in the MIR. We estimate the dust size to be a few microns from the observed color of the extended emission and the distance from the star. The dust temperature T and the optical depth τ of the MIR-emitting dust are also derived from the two images as $T = 82 \pm 1$ K, $\tau = 0.052 \pm 0.001$ for the eastern side and $T = 85 \pm 3$ K, $\tau = 0.018 \pm 0.001$ for the western side. The observed asymmetry in the brightness can be attributed to the difference in the optical depth of the MIR-emitting dust. To account for the present observations, we propose an inclined disk model, in which the outer disk is inclined along the east-west direction with the eastern side being on the far side while the inner rim of the outer disk on the eastern side is directly exposed to us. The proposed model can successfully account for the MIR observations as well as the near-infrared images of the scattering light, in which the asymmetry is seen in the opposite sense and in which the forward scattering light (near sidewestern side) is brighter.

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Inner Rim of A Molecular Disk Spatially Resolved in Infrared CO Emission Lines

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We present high-resolution infrared spectroscopy of the Herbig Ae star HD 141569 A in the CO $v = 2 - 1$ transition. With the angular resolution attained by the adaptive optics system, the gas disk around HD 141569 A is spatially resolved down to its inner-rim truncation. The size of the inner clearing is 11±2 AU in radius, close to the gravitational radius of the star. The rough coincidence to the gravitational radius indicates that the viscous accretion working together with the photoevaporation by the stellar radiation has cleared the inner part of the disk.

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Mass Accretion onto T Tauri Stars

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It is now accepted that accretion onto classical T Tauri stars is controlled by the stellar magnetosphere, yet to date most accretion models have assumed that their magnetic fields are dipolar. By considering a simple steady state accretion model with both dipolar and complex magnetic fields we find a correlation between mass accretion rate and stellar mass of the form $\dot{M} \propto M_*^\alpha$, with our results consistent within observed scatter. For any particular stellar mass there can be several orders of magnitude difference in the mass accretion rate, with accretion filling factors of a few percent. We demonstrate that the field geometry has a significant effect in controlling the location and distribution of hot spots, formed on the stellar surface from the high velocity impact of accreting material. We find that hot spots are often at mid to low latitudes, in contrast to what is expected for accretion to dipolar fields, and that particularly for higher mass stars, the accretion flow is predominantly carried by open field lines.

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A correlation between the heavy element content of transiting extrasolar planets and the metallicity of their parent stars

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Context. Nine extrasolar planets with masses between 110 and 430 $M_\oplus$ are known to transit their star. The knowledge of their masses and radii allows an estimate of their composition, but uncertainties on equations of state, opacities and possible missing energy sources imply that only inaccurate constraints can be derived when considering each planet separately.
Aims. We seek to better understand the composition of transiting extrasolar planets by considering them as an ensemble, and by comparing the obtained planetary properties to that of the parent stars.
Methods. We use evolution models and constraints on the stellar ages to derive the mass of heavy elements present in the planets. Possible additional energy sources like tidal dissipation due to an inclined orbit or to downward kinetic energy transport are considered.
Results. We show that the nine transiting planets discovered so far belong to a quite homogeneous ensemble that is characterized by a mass of heavy elements that is a relatively steep function of the stellar metallicity, from less than 20 earth masses of heavy elements around solar composition stars, to up to $\sim 100\,M_\oplus$ for three times the solar metallicity (the precise values being model-dependant). The correlation is still to be ascertained however. Statistical tests imply a worst-case 1/3 probability of a false positive.
Conclusions. Together with the observed lack of giant planets in close orbits around metal-poor stars, these results appear to imply that heavy elements play a key role in the formation of close-in giant planets. The large masses of heavy elements inferred for planets orbiting metal rich stars was not anticipated by planet formation models and shows the need for alternative theories including migration and subsequent collection of planetesimals.

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Stellar Parameters and Evidence of Circumstellar Activity for a Sample of Herbig Ae/Be Stars

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Aims: Our objective in this work is to investigate evidences of accretion in a sample of 15 Herbig Ae/Be stars and try to determine whether these events originate in a remnant gaseous structure from the primordial cloud (rich in Hydrogen) or in a metal rich body (like comets in our Solar System). During such analysis we also determine precise stellar parameters for this sample of stars.
Methods: The stars were observed using high resolution spectroscopy (R = 48,000). A synthetic photospheric spectrum was constructed and then subtracted from the observed one in order to obtain the circumstellar component. An

iterative procedure was applied in order to find the stellar parameters that were used to build the synthetic photospheric spectrum.
Results: Evidences of circumstellar activity were found in four stars: HD100546, HD142666, HD144432 and HD145718. The presence of redshifted absorption features only in the Balmer lines implies that the accreting material is Hydrogen rich, excluding the possibility that the accretion events might have been created by comet-like bodies. We determined effective temperature, surface gravity, metallicity and the projected rotational velocity for the stars in our sample.

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Star Formation in the Northern Cloud Complex of NGC 2264

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We have made continuum and spectral line observations of several outflow sources in the Mon OB1 dark cloud (NGC 2264) using the Heinrich Hertz Telescope (HHT) and ARO 12 m millimeter-wave telescope. This study explores the kinematics and outflow energetics of the young stellar systems observed and assesses the impact star formation is having on the surrounding cloud environment. Our data set incorporates ^{12}CO (3-2), ^{13}CO (3-2), and ^{12}CO (1-0) observations of outflows associated with the sources IRAS 06382+1017 and IRAS 06381+1039, known as IRAS 25 and 27, respectively, in the northern cloud complex. Complementary 870μm continuum maps were made with the HHT 19 channel bolometer array. Our results indicate there is a weak 0.5% coupling between outflow kinetic energy and turbulent energy of the cloud. An analysis of the energy balance in the IRAS 25 and 27 cores suggests they are maintaining their dynamical integrity except where outflowing material directly interacts with the core, such as along the outflow axes.

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Planetesimal Capture in the Disk Instability Model

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We follow the contraction and evolution of a typical Jupiter-mass clump created by the disk instability mechanism, and compute the rate of planetesimal capture during this evolution. We show that such a clump has a slow contraction phase lasting $\sim 3 \times 10^5$ years. By following the trajectories of planetesimals as they pass through the envelope of the protoplanet, we compute the cross-section for planetesimal capture at all stages of the protoplanet's evolution. We show that the protoplanet can capture a large fraction of the solid material in its feeding zone, which will lead to an enrichment of the protoplanet in heavy elements. The exact amount of this enrichment depends upon, but is not very sensitive to the size and random speed of the planetesimals.

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Evidence for Differential Rotation on a T Tauri Star

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Five years of photometric monitoring of the T Tauri star HBC 338 in NGC 1333 has revealed that it is a periodic variable, but the period has changed significantly with time. From 2000-2003, a period near 5.6 days was observed, while in the last two seasons, the dominant period is near 4.6 days. No other T Tauri star has been seen to change its period by such a large percentage. We propose a model in which a differentially rotating star is seen nearly equator-on and a high latitude spot has gradually been replaced by a low latitude spot. We show that this model provides an excellent fit to the observed shapes of the light curves at each epoch. The amplitude and sense of the inferred differential rotation is similar to what is seen on the Sun. This may be surprising given the likely high degree of magnetic surface activity on the star relative to the Sun but we note that HBC 338 is clearly an exceptional T Tauri star.

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Self-gravity driven instabilities of interfaces in the interstellar medium

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In order to understand star formation it is important to understand the dynamics of atomic and molecular clouds in the interstellar medium (ISM). Non-linear hydrodynamic flows are a key component to the ISM. One route by which non-linear flows arise is the onset and evolution of interfacial instabilities. Interfacial instabilities act to modify the interface between gas components at different densities and temperatures. Such an interface may be subject to a host of instabilities, including the Rayleigh-Taylor, Kelvin-Helmholtz, and Richtmyer-Meshkov instabilities. Recently, a new density interface instability was identified. This self-gravity interfacial instability (SGI) causes any displacement of the interface to grow on roughly a free-fall time-scale, even when the perturbation wavelength is much less than the Jeans length. In previous work, we used numerical simulations to confirm the expectations of linear theory and examine the non-linear evolution of the SGI. We now continue our study by generalizing our initial conditions to allow the acceleration due to self-gravity to be non-zero across the interface. We also consider the behaviour of the SGI for perturbation wavelengths near the Jeans wavelength. We conclude that the action of self-gravity across a density interface may play a significant role in the ISM either by fuelling the growth of new instabilities or modifying the evolution of existing instabilities.

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Spectroscopy of Young Planetary Mass Candidates with Disks

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It is now well established that many young brown dwarfs exhibit characteristics similar to classical T Tauri stars, including infrared excess from disks and emission lines related to accretion. Whether the same holds true for even lower mass objects, namely those near and below the Deuterium-burning limit, is an important question. Here we present optical spectra of six isolated planetary mass candidates in Chamaeleon II, Lupus I and Ophiuchus star-forming regions, recently identified by Allers and collaborators to harbor substantial mid-infrared excesses. Our spectra, from ESO's Very Large Telescope and New Technology Telescope, show that four of the targets have spectral types in the ~M9-L1 range, and three of those also exhibit Hα. Their luminosities are consistent with masses of ~5-15 $M_{Jupiter}$ according to models of Chabrier, Baraffe and co-workers, thus placing these four objects among the lowest mass brown dwarfs known to be surrounded by circum-sub-stellar disks. Our findings bolster the idea that free-floating planetary mass objects could have infancies remarkably similar to those of Sun-like stars and suggest the intriguing possibility

of planet formation around primaries whose masses are comparable to those of extra-solar giant planets. Another target appears to be a brown dwarf (∼M8) with prominent Hα emission, possibly arising from accretion. The sixth candidate is likely a background source, underlining the need for spectroscopic confirmation.

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Modeling the gas-phase chemistry of the transitional disk around HD 141569A

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Aims. The chemistry, distribution and mass of the gas in the transitional disk around the 5 Myr old B9.5 V star HD 141569A are constrained.
Methods. A quasi 2-dimensional (2D) chemistry code for photon dominated regions (PDR) is used to calculate the chemistry and gas temperatures in the disk. The calculations are performed for several gas distributions, PAH abundances and values of the total gas mass. The resulting CO $J = 2-1$ and $J = 3-2$ emission lines are computed with a 2D radiative transfer code and are compared to observations.
Results. The CO abundance is very sensitive to the total disk mass because the disk is in a regime where self-shielding just sets in. The observed CO emission lines are best fit by a power-law gas distribution of 80 $M_\oplus$ starting at 80 AU from the central star, indicating that there is some gas in the inner hole. Predictions are made for intensities of atomic fine-structure lines. [CI], which is the dominant form of carbon in large parts of the disk, is found to be a good alternative tracer of the gas mass.

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Low-mass star formation in Lynds 1333

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Medium-resolution optical spectroscopy of the candidate YSOs associated with the small, nearby molecular cloud Lynds 1333 revealed four previously unknown classical T Tauri stars, two of which are components of a visual double, and a Class I source, *IRAS* 02086+7600. The spectroscopic data, together with new V, R_C, I_C photometric and 2MASS J, H, and K_s data allowed us to estimate the masses and ages of the new T Tauri stars. We touch on the possible scenario of star formation in the region. L 1333 is one of the smallest and nearest known star forming clouds, therefore it may be a suitable target for studying in detail the small scale structure of a star forming environment.

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Diffuse Far-Ultraviolet Observations of the Taurus Region

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Diffuse far-ultraviolet (FUV; 1370 – 1670 Å) flux from the Taurus molecular cloud region has been observed with the SPEAR/FIMS imaging spectrograph. An FUV continuum map of the Taurus region, similar to the visual extinction maps, shows a distinct cloud core and halo region. The dense cloud core, where the visual extinction $A_v > 1.5$, obscures the background diffuse FUV radiation, while scattered FUV radiation is seen in and beyond the halo region, where $A_v < 1.5$. The total intensity of H_2 fluorescence in the cloud halo is $IH_2 = 6.5 \times 10^4$ photons cm^{-2} s^{-1} sr^{-1} in the 1370 – 1670 Å wavelength band. A synthetic model of the H_2 fluorescent emission fits the present observation best with a hydrogen density $n_H = 50$ cm^{-3}, H_2 column density $N(H_2) = 0.8 \times 10^20$ cm^{-2}, and incident FUV intensity $I_{UV} = 0.2$. H_2 fluorescence is not seen in the core, presumably because the required radiation flux to induce fluorescence is unable to penetrate the core region.

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Optical imaging of L723: the structure of HH 223

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Aims. We imaged the Lynds 723 dark nebula (L723) with the aim of studying the morphology of the Herbig-Haro object HH 223 and other line-emission nebula detected in the region.
Methods. We obtained deep narrow-band images in the Hα and [SII] lines and in the continuum nearby Hα of a field of $\sim 5'$ of the L723 dark nebula centered on HH 223.
Results. The Hα and [SII] images reveal the detailed morphology of HH 223, unresolved in previous optical images. Both images show a quite complex knotty, wiggling structure embedded in a low-emission nebula. Comparison between the [SII] and Hα fluxes of the knots are indicative of variations in the excitation conditions through HH 223. In addition, several other faint nebula are detected in Hα a few arcmin to the SE and to the NW of HH 223, all of them lying projected onto the east-west pair of lobes of the quadrupolar CO outflow. Comparison between the Hα and the continuum images confirms the HH-like nature of the Vrba object V83, while the Vrba objects V84 and V85 are identified as faint field stars.

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The Spatial Distribution of Brown Dwarfs in Taurus

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By combining photometry from the 2MASS Point Source Catalog and the USNO-B1.0 catalog with optical and infrared spectroscopy, I have performed a search for young brown dwarfs in an area of 225 deg^2 encompassing all of the Taurus star-forming region ($\tau \sim 1$ Myr). From this work, I have discovered 22 new members of Taurus, 5 of which were independently found by Guieu and coworkers. Sixteen of these new members have spectral types later than M6 and thus are likely to be brown dwarfs according to the theoretical evolutionary models of Chabrier and Baraffe. After adding these new members to the previously known members of Taurus, I have compared the spatial distributions of stars and brown dwarfs across the entire region. I find no statistically significant difference between these two distributions. Taurus does not contain the large, extended population of brown dwarfs that has been predicted by some embryo ejection models for the formation of brown dwarfs. However, these results are consistent with other ejection models, as well as models in which stars and brown dwarfs share a common formation mechanism.

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Magnetic jets from swirling discs

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A broad swathe of astrophysical phenomena, ranging from tubular planetary nebulae through HerbigHaro objects, radio galaxy and quasar emissions to gamma-ray bursts and perhaps high-energy cosmic rays, may be driven by magnetically dominated jets emanating from accretion discs. We give a self-contained account of the analytic theory of non-relativistic magnetically dominated jets wound up by a swirling disc and making a magnetic cavity in a background medium of any prescribed pressure, $p(z)$. We solve the time-dependent problem for any specified distribution of magnetic flux $P(R, 0)$ emerging from the disc at $z = 0$, with any specified disc angular velocity $d(R)$. The physics required to do this involves only the freezing of the lines of force to the conducting medium and the principle of minimum energy.

In a constant pressure environment, the magnetically dominated cavity is highly collimated and advances along the axis at a constant speed closely related to the maximum circular velocity of the accretion disc. Even within the cavity the field is strongly concentrated towards the axis. The twist in the jet field $< B_\phi > / < |B_z| >$ is close to $\sqrt{2}$ and the width of the jet decreases upwards. By contrast, when the background pressure falls off with height with powers approaching z^{-4}, the head of the jet accelerates strongly and the twist of the jet is much smaller. The width increases to give an almost conical magnetic cavity with apex at the source. Such a regime may be responsible for some of the longest strongly collimated jets. When the background pressure falls off faster than z^{-4}, there are no quasi-static configurations of well-twisted fields and the pressure confinement is replaced by a dynamic effective pressure or a relativistic expansion. In the regimes with rapid acceleration, the outgoing and incoming fields linking the twist back to the source are almost anti-parallel so there is a possibility that magnetic reconnections may break up the jet into a series of magnetic 'smoke-rings' travelling out along the axis.

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Second Core Formation and High Speed Jets: Resistive MHD Nested Grid Simulations

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The stellar core formation and high speed jets driven by the formed core are studied by using three-dimensional resistive MHD nested grid simulations. Starting with a Bonnor-Ebert isothermal cloud rotating in a uniform magnetic field, we calculate the cloud evolution from the molecular cloud core ($n_c = 10^6\,\mathrm{cm}^{-3}$) to the stellar core ($n_c \simeq 10^{23}\,\mathrm{cm}^{-3}$), where n_c denotes the central density. For comparison, we calculate two models: resistive and ideal MHD models. Both models have the same initial condition, but the former includes dissipation process of magnetic field while the latter does not. The magnetic fluxes in resistive MHD model are extracted from the first core during $10^{12}\,\mathrm{cm}^{-3} < n_c < 10^{16}\,\mathrm{cm}^{-3}$ by Ohmic dissipation. Magnetic flux density of the formed stellar core ($n_c \simeq 10^{20}\,\mathrm{cm}^{-3}$) in resistive MHD model is two orders of magnitude smaller than that in ideal MHD model. Since magnetic braking is less effective in resistive MHD model, rapidly rotating stellar core (the second core) is formed. After stellar core formation, the magnetic field of the core is largely amplified, and high speed ($\simeq 45\,\mathrm{km\,s}^{-1}$) jets are driven by the second core, which results in strong mass ejection. A cocoon-like structure around the second core also forms with clear bow shocks.

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Synchrotron emission from the T Tauri binary system V773 Tauri A

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The pre-main sequence binary system V773 Tau A shows remarkable flaring activity around periastron passage. Here, we present the observation of such a flare at a wavelength of 3 mm (90 GHz) performed with the Plateau de Bure Interferometer. We examine different possible causes for the energy losses responsible for the e-folding time of 2.31±0.19 h of that flare. We exclude synchrotron, collisional, and inverse Compton losses because they are not consistent with observational constraints, and we propose that the fading of the emission is due to the leakage of electrons themselves at each reflection between the two mirror points of the magnetic structure partially trapping them. The magnetic structure compatible with both our leakage model and previous observations is that of a helmet streamer that, as in the solar case, can occur at the top of the X-ray-emitting, stellar-sized coronal loops of one of the stars. The streamer may extend up to $\sim 20 R_{star}$ and interact with the corona of the other star at periastron passage, causing recurring flares. The inferred magnetic field strength at the two mirror points of the helmet streamer is in the range 0.12-125 G, and the corresponding Lorentz factor, γ, of the partially trapped electrons is in the range $20 < \gamma < 632$. We therefore rule out that the emission could be of gyro-synchrotron nature: the derived high Lorentz factor proves that the nature of the emission at 90 GHz from this pre-main binary system is synchrotron radiation.

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Study of Photon Dominated Regions in Cepheus B

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Aims. The aim of the paper is to understand the emission from the photon dominated regions in Cepheus B, estimate the column densities of neutral carbon in bulk of the gas in Cepheus B and to derive constraints on the factors which determine the abundance of neutral carbon relative to CO.
Methods. This paper presents $15' \times 15'$ fully sampled maps of [C I] at 492 GHz and ^{12}CO 4–3 observed with KOSMA at $1'$ resolution. The new observations have been combined with the FCRAO ^{12}CO 1–0, IRAM-30m ^{13}CO 2–1 and $C^{18}O$ 1–0 data, and far-infrared continuum data from HIRES/IRAS. The KOSMA-τ spherical PDR model has been used to understand the [C I] and CO emission from the PDRs in Cepheus B and to explain the observed variation of the relative abundances of both C^0 and CO.
Results. The emission from the PDR associated with Cepheus B is primarily at $V_{\rm LSR}$ between -14 and -11 km s^{-1}. We estimate about 23% of the observed [C II] emission from the molecular hotspot is due to the ionized gas in the H II region. Over bulk of the material the C^0 column density does not change significantly, $(2.0 \pm 1.4)\,10^{17}\,{\rm cm}^{-2}$, although the CO column density changes by an order of magnitude. The observed C/CO abundance ratio varies between 0.06 and 4 in Cepheus B. We find an anti-correlation of the observed C/CO abundance ratio with the observed hydrogen column density, which holds even when all previous observations providing C/CO ratios are included. Here we show that this observed variation of C/CO abundance with total column density can be explained only by clumpy PDRs consisting of an ensemble of clumps. At high H_2 column densities high mass clumps, which exhibit low C/CO abundance, dominate, while at low column densities, low mass clumps with high C/CO abundance dominate.

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C I 492 GHz mapping toward Cas A

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We have mapped the [C I] $^3P_1$–$^3P_0$ emission at 492 GHz toward the supernova remnant Cas A. We detect [C I] emission from the periphery of the diffuse Photon Dominated Region (PDR) covering the disk of Cas A, as traced by the carbon recombination lines, as well as from the denser PDRs associated with the molecular clouds towards the south-east. [C I] emission is detected from both the Perseus and Orion arm molecular clouds, with the -47 km s^{-1} Perseus arm feature being strong enough to be detected at all positions. We estimate the C/CO relative abundance to be 0.2 at the position of the identified CO clouds and > 1 for most of the cloud. Here we show that the distribution of [C I] emitting regions compared to the C^+ region and molecular cloud is consistent with a scenario involving PDRs. Using physical models for PDRs we constrain the physical properties of the [C I] line-forming regions. We estimate the densities of the [C I] emitting regions to be between 10^2 and 10^3 cm^{-3}. Based on rather high volume filling factors ($\sim 50\%$) we conclude that [C I] emission mainly arises from diffuse neutral gas in the Perseus arm.

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On the Hydrodynamic Interaction of Shock Waves with Interstellar Clouds. II. The Effect of Smooth Cloud Boundaries on Cloud Destruction and Cloud Turbulence

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The effect of smooth cloud boundaries on the interaction of steady planar shock waves with interstellar clouds is studied using a local adaptive mesh refinement technique with an axisymmetric Godunov hydrodynamic scheme. A three-dimensional calculation is also done to confirm the two-dimensional results. We find that smooth cloud boundaries significantly affect cloud morphology and retard cloud destruction. After shock passage, a sharp density jump forms due to velocity gradients generated in the smooth cloud boundary. We refer to this density jump as a "slip surface" because the velocity is sheared parallel to its surface. The formation of a slip surface leads to complete cloud destruction because of the Kelvin-Helmholtz and Rayleigh-Taylor instabilities. We construct analytic models of cloud drag and vorticity generation that compare well with the numerical results. Small shreds formed by the instabilities have significant velocity dispersions of 10%-20% of the ambient shock velocity. They could be related to the small cold HI clouds recently observed by Stanimirović & Heiles. The dependence of the velocity dispersion on region size, the so-called line widthsize relation, is found to be time-dependent. In the early stages, the line widthsize relation is more or less flat because of the significant small-scale fluctuations generated by the Kelvin-Helmholtz instability. In the later stages, the small-scale fluctuations tend to damp, leading to a line width that increases with size. The possibility of gravitational instability triggered by shock compression is discussed. We show that gravitational collapse can be induced in an initially uniform cloud by a radiative shock ($\gamma < 4/3$) only if it is not too strong and nonthermal motions are weak.

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The Variability and Rotation of Pre-main Sequence Stars in IC 348: Does Intracluster Environment Influence Stellar Rotation?

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A variability study of the young cluster IC 348 at Van Vleck Observatory has been extended to a total of seven years. Twelve new periodic stars have been found in the last two years, bringing the total discovered by this program to 40. In addition, we confirm 16 of the periods reported by others and resolve some discrepancies. The total number of known rotation periods in the cluster, from all studies has now reached 70. This is sufficient to demonstrate that the parent population of K5-M2 stars is rotationally indistinguishable from that in the Orion Nebula Cluster even though their radii are 20% smaller and they would be expected to spin about twice as fast if angular momentum were conserved. The median radius and, therefore, inferred age of the IC 348 stars actually closely matches that of NGC 2264, but the stars spin significantly more slowly. This suggests that another factor besides mass and age plays a role in establishing the rotation properties within a cluster and we suggest that it is environment. If disk locking were to persist for longer times in less harsh environments, because the disks themselves persist for longer times, it could explain the generally slower rotation rates observed for stars in this cluster, whose earliest type star is of class B5. We have also obtained radial velocities, the first for PMS stars in IC348, and v sin i measurements for 30 cluster stars to assist in the study of rotation and as an independent check on stellar radii. Several unusual variable stars are discussed; in some or all cases their behavior may be linked to occultations by circumstellar material. A strong correlation exists between the range of photometric variability and the slope of the spectral energy distribution in the infrared. Nineteen of the 21 stars with I ranges exceeding 0.4 mag show infrared evidence for circumstellar disks.

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The Recurrent Eclipse of an Unusual Pre–Main-Sequence Star in IC 348

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The recurrence of a previously documented eclipse of a solar-like pre–main-sequence star in the young cluster IC 348 has been observed. The recurrence interval is 4.7 ± 0.1 yr and portions of 4 cycles have now been seen. The duration of each eclipse is at least 3.5 years, or $\sim 75\%$ of a cycle, verifying that this is not an eclipse by a stellar companion. The light curve is generally symmetric and approximately flat-bottomed. Brightness at maximum and minimum have been rather stable over the years but the light curve is not perfectly repetitive or smooth and small variations exist at all phases. We confirm that the star is redder when fainter. Models are discussed and it is proposed that this could be a system similar to KH 15D in NGC 2264. Specifically, it may be an eccentric binary in which a portion of the orbit of one member is currently occulted during some binary phases by a circumbinary disk. The star deserves sustained observational attention for what it may reveal about the circumstellar environment of low-mass stars of planet-forming age.

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Dust flow in gas disks in the presence of embedded planets

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Aims. We study the dynamics of gas and dust in a protoplanetary disk in the presence of embedded planets. We investigate the conditions for dust-gap formation in terms of particle size and planetary mass. We also monitor the amount of dust that is accreted by the planet relative to the amount of gas, which is an important parameter in determining the enrichment of solids in giant planets compared to the solid content of the central star.
Methods. We use a new two-fluid hydrodynamics code to solve the flow equations for both gas and dust. For the gas, we use a Godunov-type scheme with an approximate Riemann solver (the Roe solver). The dust is treated as a pressureless fluid by essentially the same numerical method as is used for the gas.
Results. We find that it only takes a planet of 0.05 Jupiter masses to open up a gap in a disk with a significant population of mm-sized particles. Dust particles larger than 150 μm participate in gap formation. We also find that the formation of the gap severely slows down dust accretion compared to that in the gas. Therefore, it is not possible to enrich a newly formed giant planet in solids, if these solids are contained in particles with sizes from 150 μm to approximately 10 cm.

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CO and CH_3OH observations of the BHR71 outflows with APEX

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Context: Highly-collimated outflows are believed to be the earliest stage in outflow evolution, so their study is essential for understanding the processes driving outflows. The BHR71 Bok globule is known to harbour such a highly-collimated outflow, which is powered by a protostar belonging to a protobinary system.
Aims: We aimed at investigating the interaction of collimated outflows with the ambient molecular cloud by using molecular tracers.
Methods: We mapped the BHR71 highly-collimated outflow in CO(3-2) with the APEX telescope, and observed several bright points of the outflow in the molecular transitions CO(4-3), ^{13}CO(3-2), C^{18}O(3-2), and CH_3OH(7-6). We use an LVG code to characterise the temperature enhancements in these regions.
Results: In our CO(3-2) map, the second outflow driven by IRS2, which is the second source of the binary system, is completely revealed and shown to be bipolar. We also measure temperature enhancements in the lobes. The CO and methanol LVG modelling points to temperatures between 30 and 50 K in the IRS1 outflow, while the IRS2 outflow seems to be warmer (up to 300 K).

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Formation and Evolution of Planetary Systems: Upper Limits to the Gas Mass in Disks Around Sun-like Stars

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We have carried out a sensitive search for gas emission lines at infrared and millimeter wavelengths for a sample of 15 young sun–like stars selected from our dust disk survey with the Spitzer Space Telescope. We have used midinfrared lines to trace the warm (300–100 K) gas in the inner disk and millimeter transitions of 12CO to probe the cold (∼20 K) outer disk. We report no gas line detections from our sample. Line flux upper limits are first converted to warm and cold gas mass limits using simple approximations allowing a direct comparison with values from the literature. We also present results from more sophisticated models following Gorti and Hollenbach (2004) which confirm and extend our simple analysis. These models show that the [SI] line at 25.23 micron can set constraining limits on the gas surface density at the disk inner radius and traces disk regions up to a few AU. We find that none of the 15 systems have more than 0.04 MJ of gas within a few AU from the disk inner radius for disk radii from 1 AU up to ∼40 AU. These gas mass upper limits even in the 8 systems younger than ∼30 Myr suggest that most of the gas is dispersed early. The gas mass upper limits in the 10–40 AU region, that is mainly traced by our CO data, are < 2 Mearth . If these systems are analogs of the Solar System, either they have already formed Uranus and Neptunelike planets or they will not form them beyond 100 Myr. Finally, the gas surface density upper limits at 1 AU are smaller than 0.01sources. If terrestrial planets form frequently and their orbits are circularized by gas, then circularization occurs early.

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Differential Radial Velocities and Stellar Parameters of Nearby Young Stars

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Radial velocity searches for substellar-mass companions have focused primarily on stars older than 1 Gyr. Increased levels of stellar activity in young stars hinders the detection of solar system analogs, and therefore until recently there has been a prejudice against inclusion of young stars in radial velocity surveys. Adaptive optics surveys of young stars have given us insight into the multiplicity of young stars, but only for massive, distant companions. Understanding the limit of the radial velocity technique, restricted to high-mass, close-orbiting planets and brown dwarfs, we began a survey of young stars of various ages. While the number of stars needed to carry out full analysis of the problems of planetary and brown dwarf population and evolution is large, the beginning of such a sample is included here. We report on 61 young stars ranging in age from the β Pictoris association ($\sim$ 12 Myr) to the Ursa Major association ($\sim$ 300 Myr). This initial search resulted in no stars showing evidence of companions larger than $\sim 1M_{Jup} - 2M_{Jup}$ in short-period orbits at the 3σ level. We also present derived stellar parameters, as most have unpublished values. The chemical homogeneity of a cluster, and presumably of an association, may help to constrain true membership, so we present [Fe/H] abundances for the stars in our sample.

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Submillimeter imaging spectroscopy of the Horsehead nebula

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We present $\sim$ 15 arcsecond resolution single-dish imaging of the Horsehead nebula in the CI (1-0) and CO (4-3) lines, carried out using the CHAMP array at the Caltech Submillimeter Observatory (CSO). The data are used together with supporting observations of the (2-1) transitions of the CO isotopologues to determine the physical conditions in the atomic and molecular gas via Photon Dominated Region (PDR) modeling. The CO (4-3)/(2-1) line ratio, which is an excellent tracer of the direction of the incoming UV photons, increases at the western and northern edges of the nebula, confirming that the illumination is provided mostly by the stars σ and ζ Orionis. The observed line intensities are consistent with PDR models with an H nuclei volume density of $\sim 3-7 \times 10^4$ cm^{-3}. The models predict a kinetic temperature of $\sim$ 12 K and a $C^{18}O$ fractional abundance with respect to H atoms of 2.4×10^{-7} in the shielded region,

which in turn imply a total molecular mass of ~ 24 $M_\odot$ in the $C^{18}O$ filament. The outer halo, devoid of $C^{18}O$, but traced by the CI emission has a comparable density and contributes additional ~ 13 $M_\odot$ of material, resulting in an upper limit of ~ 37 $M_\odot$ for the total molecular mass of the nebula.

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Comparison of Magnetic Field Structures on Different Scales in and around the Filamentary Dark Cloud GF 9

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New visible polarization data combined with existing IR and FIR polarization data are used to study how the magnetic field threading the filamentary molecular cloud GF 9 connects to larger structures in its general environment. We find that when both visible and NIR polarization data are plotted as a function of extinction, there is no evidence for a plateau or a saturation effect in the polarization at $A_V \approx 1.3$ as seen in dark clouds in Taurus. This lack of saturation effect suggests that even in the denser parts of GF 9 we are still probing the magnetic field. The visible polarization is smooth and has a well-defined orientation. The IR data are also well defined but with a different direction, and the FIR data in the core region are well defined and with yet another direction, but are randomly distributed in the filament region. On the scale of a few times the mean radial dimension of the molecular cloud, it is as if the magnetic field were 'blind' to the spatial distribution of the filaments while on smaller scales within the cloud, in the core region near the IRAS point source PSC 20503+6006, polarimetry shows a rotation of the magnetic field lines in these denser phases. Hence, in spite of the fact that the spatial resolution is not the same in the visible/NIR and in the FIR data, all the data put together indicate that the field direction changes with the spatial scale. Finally, the Chandrasekhar and Fermi method is used to evaluate the magnetic field strength, indicating that the core region is approximately magnetically critical. A global interpretation of the results is that in the core region an original poloidal field could have been twisted by a rotating elongated (core+envelope) structure. There is no evidence for turbulence and ambipolar diffusion does not seem to be effective at the present time.

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Adaptive Optics Spectroscopy of the [Fe II] Outflows from HL Tauri and RW Aurigae

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We present new results of [Fe II] $\lambda 1.644$ μm spectroscopy toward the jets from HL Tau and RW Aur carried out with the Subaru Telescope combined with the adaptive optics system. We observed the regions within $2''$–$3''$ from the stars with the sub-arcsecond resolutions of $0.''5$ and $0.''2$ for HL Tau and RW Aur, respectively. In addition to the strong, high velocity emission extended along each jet, we detected a blueshifted low velocity emission feature seen as a wing or shoulder of the high velocity emission at each stellar position. Detailed analysis shows that the low velocity emission of HL Tau is peaked at 0.″077 ± 0.″04 away from the stellar position, or 15 AU of actual distance from the star. We did not confirm such displacement for RW Aur in its position velocity diagram (PVD). The PVDs of HL Tau and RW Aur show a characteristic similar to those of the cold disk wind and X-wind models in that the [Fe II] line width is broad in the vicinity of the stellar position and is narrower at the extended jet. A closer comparison suggests, however, that the disk wind model tends to have too large line width at the jet while the X-wind model has excess emission on the redshifted side at the stellar position. The narrow velocity width with symmetric line profiles of the observed high velocity emission supports an X-wind type model where the launching region is localized in a small radial range, while the low velocity emission located away from the star favors the presence of a disk wind. The [Fe II] emission from the HL Tau jet shows a gap of 0.″8 between the redshifted jet and the star, indicating the presence of an optically thick disk of ∼160 AU in radius. The [Fe II] emission from the RW Aur jet shows a marked drop from the redshifted peak at $Y \sim -0.''2$ toward the star, suggesting that its disk radius is smaller than 40 AU. The normalized Br12 emission of HL Tau shows a significantly large deviation from the normalized continuum in spatial profile along the blueshifted jet. It means that part of the Br12 emission originates in the blueshifted jet itself.

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Molecular Line Observations of Infrared Dark Clouds: Seeking the Precursors to Intermediate and Massive Star Formation

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We have identified 41 infrared dark clouds from the 8 micron maps of the Midcourse Space Experiment (MSX), selected to be found within one square degree areas centered on known ultracompact HII regions. We have mapped these infrared dark clouds in N2H+(1-0), CS(2-1) and C18O(1-0) emission using the Five College Radio Astronomy Observatory. The maps of the different species often show striking differences in morphologies, indicating differences in evolutionary state and/or the presence of undetected, deeply embedded protostars. We derive an average mass for these clouds using N2H+ column densities of 2500 solar masses, a value comparable to that found in previous studies of high mass star forming cores using other mass tracers. The linewidths of these clouds are typically 2.0 - 2.9 km/s. Based on the fact that they are dark at 8 micron, compact, massive, and have large velocity dispersions, we suggest that these clouds may be the precursor sites of intermediate and high mass star formation.

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High-Mass Star Formation. II. The Mass Function of Submillimeter Clumps in M17

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We have mapped a ∼ 5.5 × 5.5 pc portion of the M17 massive star-forming region in both 850 and 450μm dust continuum emission using the Submillimeter Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT). The maps reveal more than 100 dusty clumps with deconvolved linear sizes of ∼ 0.05-0.2 pc and masses of ∼ 0.8-120 $M_\odot$, most of which are not associated with known mid-infrared point sources. Fitting the clump mass function with a double power law gives a mean power-law exponent of $\alpha_{high} = -2.4 \pm 0.3$ for the high-mass power law, consistent with the exponent of the Salpeter stellar mass function. We show that a lognormal clump mass distribution with a peak at 4 $M_\odot$ produces as good a fit to the clump mass function as does a double power law. This 4 M_{odot} peak mass is well above the peak masses of both the stellar initial mass function and the mass function of clumps in low-mass star-forming regions. Despite the difference in intrinsic mass scale, the shape of the M17 clump mass function appears to be consistent with the shape of the core mass function in low-mass star-forming regions. Thus, we suggest that the clump mass function in high-mass star-forming regions may be a scaled up version of that in low-mass regions, instead of its extension to higher masses.

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The Magnetospheric Gap and the Accumulation of Giant Planets Close to a Star

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The bunching of giant planets at a distance of several stellar radii may be explained by the disruption of the inner part of a disk by the magnetosphere of a star during the T Tauri stage of evolution. The rotating magnetic field of the star gives rise to a low-density magnetospheric gap where stellar migration is strongly suppressed. We performed full three-dimensional (3D) magnetohydrodynamic simulations of the disk-magnetosphere interaction and examined conditions for which the magnetospheric gap is "empty," by changing the misalignment angle between the magnetic and rotational axes of the star, Θ, and by lowering the adiabatic index γ, which is a mock-up of the effect of heat conductivity and cooling. Our simulations show that for a wide range of plausible conditions, the gap is essentially empty. However, in the case of large misalignment angles Θ, part of the funnel stream is located in the equatorial plane, and the gap is not empty. Furthermore, if the adiabatic index is small ($\gamma \sim 1.1$), and the rotational and magnetic axes are almost aligned, then matter penetrates through the magnetosphere due to 3D instabilities, forming high-density equatorial funnels. For these two limits, there is appreciable matter density in the equatorial plane of the disk so that a planet may migrate into the star.

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Bias-free Measurement of Giant Molecular Cloud Properties

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We review methods for measuring the sizes, line widths, and luminosities of giant molecular clouds (GMCs) in molecular-line data cubes with low resolution and sensitivity. We find that moment methods are robust and sensitive, making full use of both position and intensity information, and we recommend a standard method to measure the position angle, major and minor axis sizes, line width, and luminosity using moment methods. Without corrections for the effects of beam convolution and sensitivity to GMC properties, the resulting properties may be severely biased. This is particularly true for extragalactic observations, where resolution and sensitivity effects often bias measured values by 40% or more. We correct for finite spatial and spectral resolutions with a simple deconvolution, and we correct for sensitivity biases by extrapolating properties of a GMC to those we would expect to measure with perfect sensitivity (i.e., the 0 K isosurface). The resulting method recovers the properties of a GMC to within 10% over a large range of resolutions and sensitivities, provided the clouds are marginally resolved with a peak signal-to-noise ratio greater than 10. We note that interferometers systematically underestimate cloud properties, particularly the flux from a cloud. The degree of bias depends on the sensitivity of the observations and the (u, v) coverage of the observations. In an Appendix to the paper we present a conservative, new decomposition algorithm for identifying GMCs in molecular-line observations. This algorithm treats the data in physical rather than observational units (i.e., parsecs rather than beams or arcseconds), does not produce spurious clouds in the presence of noise, and is sensitive to a range of morphologies. As a result, the output of this decomposition should be directly comparable among disparate

data sets.

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Evolution of First Cores in Rotating Molecular Cores

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We investigate the effect of rotation on the star formation process quantitatively using axisymmetric numerical calculations. An adiabatic hydrostatic object (the so-called first core) forms in a contracting cloud core, after the central region becomes optically thick and continues to contract, driven by mass accretion onto it. The structure of a rotating first core is characterized by its total angular momentum J_{core} and mass M_{core}, both of which increase by accretion with time. We find that the first core evolves with a constant J_{core}/M_{core}^2. Evolutionary paths of first cores can be classified into two types. In a slowly rotating core with $J_{core}/M_{core}^2 < 0.015G/(\sqrt{2}c_{iso})$, where c_{iso} and G represent the isothermal sound speed in the molecular cloud core and the gravitational constant, respectively, the core begins "second collapse" after the central density exceeds the H_2 dissociation density. This is the same evolution as a standard scenario for a spherically symmetric, nonrotating core. On the other hand, a core with $J_{core}/M_{core}^2 > 0.015G/(\sqrt{2}c_{iso})$ stops its contraction before the central density reaches the H_2 dissociation density and does not begin the second collapse. These rapidly rotating first cores suffer from nonaxisymmetric instabilities, such as formation of massive spiral arms, deformation into a bar, or fragmentation. Although the rotating first cores have small average luminosities of $L_{core} = 0.003\text{-}0.03(\dot{M}_{core}/10^{-5}M_{\odot}yr^{-1})L_{\odot}$, assuming a constant mass accretion rate core. Their lifetimes last several thousand years or more, which is much longer than those expected for nonrotating clouds ($\sim$ 1000 yr). We expect that at least several percent of prestellar cores contain first cores as very low luminosity objects. Furthermore, we find a core with $0.012G/(\sqrt{2}c_{iso}) < J_{core}/M_{core}^2 < 0.015G/(\sqrt{2}c_{iso})$ may form close binary systems with initial separation of 0.02-0.1 AU after the second collapse phase.

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Dust Processing in Disks around T Tauri Stars

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The 8-14μm emission spectra of 12 T Tauri stars in the Taurus/Auriga dark clouds and in the TW Hydrae association obtained with the Infrared Spectrograph (IRS) on board Spitzer are analyzed. Assuming that the 10μm features originate from silicate grains in the optically thin surface layers of T Tauri disks, the 8-14μm dust emissivity for each object is derived from its Spitzer spectrum. The emissivities are fit with the opacities of laboratory analogs of cosmic dust. The fits include small nonspherical grains of amorphous silicates (pyroxene and olivine), crystalline silicates (forsterite and pyroxene), and quartz, together with large fluffy amorphous silicate grains. A wide range in the fraction of crystalline silicate grains, as well as large silicate grains among these stars, are found. The dust in the transitional-disk objects CoKu Tau/4, GM Aur, and DM Tau has the simplest form of silicates, with almost no hint of crystalline components and modest amounts of large grains. This indicates that the dust grains in these objects have been modified little from their origin in the interstellar medium. Other stars show various amounts of

crystalline silicates, similar to the wide dispersion of the degree of crystallinity reported for Herbig Ae/Be stars of mass $< 2.5 M_{\odot}$. Late spectral type, low-mass stars can have significant fractions of crystalline silicate grains. Higher quartz mass fractions often accompany low amorphous olivine to amorphous pyroxene ratios. Lower contrast of the 10μm feature accompanies greater crystallinity.

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A new View of the Cygnus X Region: KOSMA ^{13}CO 2→1, 3→2 and ^{12}CO 3→2 imaging

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Context: The Cygnus X region is one of the richest star formation sites in the Galaxy. There is a long standing discussion whether the region is a by chance superposition of several complexes along the line of sight or a single coherent complex at a distance of 1.5 to 2 kpc.
Aims: Combining a ^{13}CO 2→1 survey taken with the KOSMA 3m telescope with mid-IR images from MSX provides a way to improve our understanding of the 3-dimensional structure of the complex. The physical properties of the molecular gas can be derived in more detail as it was done in former studies.
Methods: Cygnus X has been mapped in ^{13}CO J=2→1 (10.8 deg^2) at an angular resolution of 130″, as well as for smaller areas in ^{12}CO and ^{13}CO J=3→2 (90″), using the KOSMA 3m submm-telescope.
Results: We identified 91 clumps in ^{13}CO 2→1 which have a typical of 1.3×10^3 cm^{-3}, radii of 1–8 pc, and masses of a few hundred to several ten thousand M$_{\odot}$. The main cloud complexes, the northern part (M$\simeq 2.8\times10^5$ M$_{\odot}$) including DR21 and W75N and the southern region (M$\simeq 4.5\times10^5$ M$_{\odot}$) with IC 1318 b/c and AFGL2591, show differences in their physical properties. The ^{13}CO emission is closely associated with mid-IR emission seen with MSX. We find evidence that Cygnus OB2 and Cygnus OB9 are affecting the molecular material in Cygnus X.
Conclusions: Since essentially all molecular cloud complexes in Cygnus X form groups that are connected by molecular emission (visible in channel and position-velocity maps) and partly show evidence of interaction with UV radiation, we conclude that most of the objects seen in this region are located at the same distance, i.e., that of the OB2 cluster at ∼1.7 kpc, which is also consistent with the distances of other OB associations (OB9, OB1) in Cygnus X.

The ^{13}CO 2→ data (as a fits data cube) are publicly available on
www.ph1.uni-koeln.de/workgroups/obs_astronomy/cygnusx.

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Constraints on the initial mass function of the first stars

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Motivated by theoretical predictions that the first stars were predominantly very massive, we investigate the physics of the transition from an early epoch dominated by massive Pop III stars to a later epoch dominated by familiar low-mass Pop II/I stars by means of a numerically generated catalogue of dark matter haloes coupled with a self-consistent treatment of chemical and radiative feedback. Depending on the strength of the chemical feedback, Pop III stars can contribute a substantial fraction (several per cent) of the cosmic star formation activity even at moderate redshifts, z ≈

5. We find that the three z ≈ 10 sources tentatively detected in Near Infrared Camera and Multi-Object Spectrometer (NICMOS) Ultra Deep Fields (UDFs) should be powered by Pop III stars, if these are massive; however, this scenario fails to reproduce the derived Wilkinson Microwave Anisotropy Probe (WMAP) electron scattering optical depth. Instead, both the UDFs and WMAP constraints can be fulfilled if stars at any time form with a more standard, slightly top-heavy, Larson initial mass function.

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Fragmentation of star-forming clouds enriched with the first dust

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The thermal and fragmentation properties of star forming clouds have important consequences on the corresponding characteristic stellar mass. The initial composition of the gas within these clouds is a record of the nucleosynthetic products of previous stellar generations. In this paper, we present a model for the evolution of star forming clouds enriched by metals and dust from the first supernovae (SNe), resulting from the explosions of metal-free progenitors with masses in the range 12-30 $M_{\odot}$ and 140-260 $M_{\odot}$. Using a self-consistent approach, we show that: (i) metals depleted on to dust grains play a fundamental role, enabling fragmentation to solar or subsolar mass scales already at metallicities $Z_{cr} = 10^{-6} Z_{\odot}$; (ii) even at metallicities as high as $10^{-2} Z_{\odot}$, metals diffused in the gas phase lead to fragment mass scales which are $\gtrsim$ 100 Mo; (iii) C atoms are strongly depleted on to amorphous carbon grains and CO molecules so that CII plays a minor role in gas cooling, leaving OI as the main gas-phase cooling agent in low-metallicity clouds. These conclusions hold independently of the assumed SN progenitors and suggest that the onset of low-mass star formation is conditioned to the presence of dust in the parent clouds.

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Gas-phase CO in protoplanetary disks: A challenge for turbulent mixing

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This is the first paper in a series where we study the influence of turbulent diffusion and advective transport on the chemical evolution of protoplanetary disks, using a 2D flared disk model and a 2D mixing gas-grain chemical code with surface reactions. A first interesting result concerns the abundance of gas-phase CO in the outer regions of protoplanetary disks. In this Letter we argue that the gas-phase CO concentration in the disk regions, where the temperature is lower than ∼ 25 K, can be significantly enhanced due to the combined effect of vertical and radial mixing. This finding has a potential implication for the current observational data on the DM Tau disk chemistry.

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The effect of heavy element opacity on pre-main sequence Li depletion

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Context. Recent 3-D analysis of the solar spectrum data suggests a significant change of the solar chemical composition. This may affect the temporal evolution of the surface abundance of light elements since the extension of the convective envelope is largely affected by the internal opacity value.
Aims. We analyse the influence of the adopted solar mixture on the opacity in the convective envelope of pre-main sequence (PMS) stars and thus on PMS lithium depletion. The surface Li abundance depends on the relative efficiency of several processes, some of them still not known with the required precision; this paper thus analyses one of the aspects of this "puzzle".
Methods. Focusing on PMS evolution, where the largest amount of Li burning occurs, we computed stellar models for three selected masses (0.8, 1.0 and 1.2 $M_{\odot}$, with Z=0.013, Y=0.27, $\alpha = 1.9$) by varying the chemical mixture, that is the internal element distribution in Z. We analysed the contribution of the single elements to the opacity at the temperatures and densities of interest for Li depletion. Several mixtures were obtained by varying the abundance of the most important elements one at a time; we then calculated the corresponding PMS Li abundance evolution.
Results. We found that a mixture variation does change the Li abundance: at fixed total metallicity, the Li depletion increases when increasing the fraction of elements heavier than O.

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The Gl569 Multiple System

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We report the results of high spectral and angular resolution infrared observations of the multiple system Gl569A and B that were intended to measure the dynamical masses of the brown dwarf binary believed to comprise Gl569B. Our analysis did not yield this result but, instead, revealed two surprises. First, at age 100 Myr, the system is younger than had been reported earlier. Second, our spectroscopic and photometric results provide support for earlier indications that Gl569B is actually a hierarchical brown dwarf triple rather than a binary. Our results suggest that the three components of Gl569B have roughly equal mass, 0.04 $M_{\odot}$.

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Spitzer Far-Infrared Detections of Cold Circumstellar Disks

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Observations at 70μm with the Spitzer Space Telescope have detected several stellar systems within 65 pc of the Sun. Of 18 presumably young systems detected in this study, as many as 15 have 70μm emission in excess of that expected from their stellar photospheres. Five of the systems with excesses are members of the Tucanae association. The 70μm excesses range from a factor of ~ 2 to nearly 30 times the expected photospheric emission from these stars. In contrast to the 70μm properties of these systems, there is evidence for an emission excess at 24μm for only HD 3003, confirming previous results for this star. The lack of a strong 24μm excess in most of these systems suggests that the circumstellar dust producing the IR excesses is relatively cool ($T_{dust} \lesssim 150$ K) and that there is little IR-emitting material within the inner few AU of the primary stars. Many of these systems lie close enough to Earth that the distribution of the dust producing the IR excesses might be imaged in scattered light at optical and near-IR wavelengths.

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Star formation in the vicinity of the IC 348 cluster

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Aims. We present molecular line observations of the southwestern part of the IC 348 young cluster, and we use them together with NIR and mm continuum data to determine the distribution of dense gas, search for molecular outflows, and analyze the ongoing star formation activity in the region.
Methods. Our molecular line data consists of $C^{18}O$(1–0) and N_2H^+(1–0) maps obtained with the FCRAO telescope at a resolution of about 50″ and CO(2–1) data obtained with the IRAM 30m telescope at a resolution of 11″.
Results. The dense gas southwest of IC 348 is concentrated in two groups of dense cores, each of them with a few solar masses of material and indications of CO depletion at high density. One of the core groups is actively forming stars, while the other seems starless. There is evidence for at least three bipolar molecular outflows in the region, two of them powered by previously identified Class 0 sources while the other is powered by a still not well characterized low-luminosity object. The ongoing star formation activity is producing a small stellar subgroup in the cluster. Using the observed core characteristics and the star formation rate in the cluster, we propose that similar episodes of stellar birth may have produced the subclustering seen in the halo of IC 348.

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Millimeter- and Submillimeter-Wave Observations of the OMC-2/3 Region; I. Dispersing and Rotating Core around an Intermediate-mass Protostar MMS 7

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We report the results of $H^{13}CO^+$(1–0), CO(1–0), and 3.3 mm dust continuum observations toward one of the strongest mm-wave sources in OMC-3, MMS 7, with the Nobeyama Millimeter Array (NMA) and the Nobeyama 45 m telescope. With the NMA, we detected centrally-condensed 3.3 mm dust-continuum emission which coincides with the MIR source and the free-free jet. The size and mass of the dusty condensation are 1500 × 1200 AU (P.A. ∼ 170°) and 0.36 - 0.72 $M_\odot$ (for $T_{\rm dust}$ = 26 - 50 K), respectively. Our combined $H^{13}CO^+$ observations with the 45 m telescope and the NMA have revealed a disk-like envelope around MMS 7 inside the $H^{13}CO^+$ core. The size and the mass of the disk-like envelope are 0.15 × 0.11 pc and 5.1 - 9.1 $M_\odot$ (for $T_{\rm ex}$ = 26 - 50 K), respectively. The combined map also shows that the outer portion of the disk-like envelope has a fan-shaped structure which delineates the rim of the CO(1–0) outflow observed with the NMA. The position-velocity (P-V) diagrams in the $H^{13}CO^+$ (1–0) emission show that the velocity field in the disk-like envelope is composed of a dispersing gas motion and a possible rigid-like rotation. The mass dispersing rate is estimated to be (3.4 - 6.0) × 10^{-5} $M_{\rm odot}$ yr^{-1}, which implies that MMS 7 has an ability to disperse ∼10 $M_\odot$ during the protostellar evolutional time of a few × 10^5 yr. One of the probable dispersing mechanisms is the associated molecular outflow, and another the stellar wind which has enough power (∼76 $L_\odot$) to drive the dissipation, (4.2 - 7.4) × 10^{-3} $L_\odot$. The specific angular momentum of the possible rotation in the disk-like envelope is nearly two orders of magnitude larger than that in low-mass cores. The turn-over point of the power law of the angular momentum distribution in the disk-like envelope (≤ 0.007 pc), which is likely to be related to the outer radius of the central mass accretion, is similar to the size of the 3.3 mm dust condensation. We propose that the intermediate-mass protostar MMS 7 is in the last stage of the main accretion phase and that the substantial portion of the outer gas has already been dispersed, while the mass accretion may still be on-going at the innermost region traced by the dusty condensation.

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Constraining the wind launching region in Herbig Ae stars: AMBER/VLTI spectroscopy of HD104237

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We investigate the origin of the Brγ emission of the Herbig Ae star HD104237 on Astronomical Unit (AU) scales. Using AMBER/VLTI at a spectral resolution R=1500 spatially resolve the emission in both the BrGamma line and the adjacent continuum. The visibility does not vary between the continuum and the BrGamma line, even though the line is strongly detected in the spectrum, with a peak intensity 35continuum. This demonstrates that the line and continuum emission have similar size scales. We assume that the K-band continuum excess originates in a "puffed-up" inner rim of the circumstellar disk, and discuss the likely origin of BrGamma. We conclude that this emission most likely arises from a compact disk wind, launched from a region 0.2-0.5 AU from the star, with a spatial extent similar to that of the near infrared continuum emission region, i.e, very close to the inner rim location.

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Giant Planet Accretion and Migration: Surviving the Type I Regime

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In the standard model of gas giant planet formation, a large solid core ($\sim$ 10 times the Earth's mass) forms first, then accretes its massive envelope (100 or more Earth masses) of gas. However, inward planet migration due to gravitational interaction with the protostellar gas disk poses a difficulty in this model. Core-sized bodies undergo rapid "type I" migration; for typical parameters their migration timescale is much shorter than their accretion timescale. How, then, do growing cores avoid spiraling into the central star before they ever get the chance to become gas giants? Here, we present a simple model of core formation in a gas disk that is viscously evolving. As the disk dissipates, accretion and migration timescales eventually become comparable. If this happens while there is still enough gas left in the disk to supply a Jovian atmosphere, then a window of opportunity for gas giant formation opens. We examine under what circumstances this happens, and thus, what predictions our model makes about the link between protostellar disk properties and the likelihood of forming giant planets.

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A SCUBA imaging survey of ultracompact HII regions - The environments of massive star formation

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We present a SCUBA submillimetre (450 and 850 μm) survey of the environment of 105 IRAS point sources, selected

from the Wood & Churchwell (1989a) and Kurtz et al. (1994) radio ultracompact (UC) HII region surveys. We detected a total of 155 sub-mm clumps associated with the IRAS point sources and identified three distinct types of object: ultracompact cm-wave sources that are not associated with any sub-mm emission (sub-mm quiet objects), sub-mm clumps that are associated with ultracompact cm-wave sources (radio-loud clumps); and sub-mm clumps that are not associated with any known ultracompact cm-wave sources (radio-quiet clumps). 90% of the sample of IRAS point sources were found to be associated with strong sub-mm emission. We consider the sub-mm colours, morphologies and distance-scaled fluxes of the sample of sub-mm clumps and show that the sub-mm quiet objects are unlikely to represent embedded UC HII regions unless they are located at large heliocentric distances. Many of the $2.'5$ SCUBA fields contain more than one sub-mm clump, with an average number of companions (the companion clump fraction) of 0.90. The clumps are more strongly clustered than other candidate HMPOs and the mean clump surface density exhibits a broken power-law distribution with a break at 3 pc. We demonstrate that the sub-mm and cm-wave fluxes of the majority of radio-loud clumps are in excellent agreement with the standard model of ultracompact HII regions. We speculate on the nature of the radio-quiet sub-mm clumps and, whilst we do not yet have sufficient data to conclude that they are in a pre-UC HII region phase, we argue that their characteristics are suggestive of such a stage.

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The Burst Mode of Protostellar Accretion

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We present new numerical simulations in the thin-disk approximation which characterize the burst mode of protostellar accretion. The burst mode begins upon the formation of a centrifugally balanced disk around a newly formed protostar. It is comprised of prolonged quiescent periods of low accretion rate (typically $\lesssim 10^{-7} M_\odot$ yr^{-1}) which are punctuated by intense bursts of accretion (typically $\gtrsim 10^{-4} M_\odot$ yr^{-1}, with duration $\lesssim$ 100 yr) during which most of the protostellar mass is accumulated. The accretion bursts are associated with the formation of dense protostellar/protoplanetary embryos, which are later driven onto the protostar by the gravitational torques that develop in the disk. Gravitational instability in the disk, driven by continuing infall from the envelope, is shown to be an effective means of transporting angular momentum outward, and mass inward to the protostar. We show that the disk mass always remains significantly less than the central protostar mass throughout this process. The burst phenomenon is robust enough to occur for a variety of initial values of rotation rate, frozen-in (supercritical) magnetic field, and density-temperature relations. Even in cases where the bursts are nearly entirely suppressed, a moderate increase in cloud size or rotation rate can lead to vigorous burst activity. We conclude that most (if not all) protostars undergo a burst mode of evolution during their early accretion history,

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http://www.astro.uwo.ca/~basu/pb.htm

Turbulence-driven Diffusion in Protoplanetary Disks: Chemical Effects in the Outer Regions

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The chemistry and dynamics of protoplanetary disks are likely to be intricately linked, with dynamical processes affecting the chemical composition and chemistry, in turn, controlling the ionization structure and hence the ability of a process such as the magnetorotational instability to drive turbulence. Here we present the results from chemical models of the outer disk, which include diffusive mixing driven by turbulence. We show that diffusion in the vertical direction can greatly affect the column densities of many molecules, increasing them by up to 2 orders of magnitude. Previous models have shown that disks consist of three chemically distinct layers, with the bulk of the observed molecular emission coming from a region between the cold midplane and the irradiated surface layers. Diffusion retains this structure, but increases the depth of the molecular layer, by bringing atoms and atomic ions formed by photodissociation in the layers into more shielded regions where the molecules can reform. The column densities of molecules whose abundances peak closer to the midplane, e.g., NH3 and N2H+, are not altered by diffusion. We find that diffusion does not affect the ionization fraction of the disk. We compare the calculated column densities to observations of DM Tau, LkCa 15, and TW Hya and find good agreement for many molecules for models with a diffusion coefficient of 10^{18} cm^2 s^{-1}.

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The Orbit and Occultations of KH 15D

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The unusual flux variations of the pre-main-sequence binary star KH 15D have been attributed to occultations by a circumbinary disk. We test whether or not this theory is compatible with newly available data, including recent radial velocity measurements, CCD photometry over the past decade, and photographic photometry over the past 50 years. We find the model to be successful, after two refinements: a more realistic motion of the occulting feature and a halo around each star that probably represents scattering by the disk. The occulting feature is exceptionally sharp edged, raising the possibility that the dust in the disk has settled into a thin layer and providing a tool for fine-scale mapping of the immediate environment of a T Tauri star. However, the window of opportunity is closing, as the currently visible star may be hidden at all orbital phases by as early as 2008.

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Molecular Outflows Around High-Mass Young Stellar Objects

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We present a study of molecular outflows using high-resolution mapping of the CO (1-0) line emission toward eight relatively nearby 6.7 GHz methanol masers that are associated with massive star-forming regions. Outflows were detected in seven out of eight sources, and five of them clearly show bipolar or multiple outflow morphologies. These outflows have typical masses of a few solar masses, momenta of tens of $M_\odot$ km s^{-1}, kinetic energies of $\sim 10^{45}$ ergs, and mass entrainment rates of a few $10^{-5} M_\odot$ yr^{-1}. They have significantly more mass and kinetic energy than their low-mass counterparts. In some of the sources, the massive outflow is obviously associated with a particular massive star in the cluster, while in others the origin remains uncertain. The high detection rate of outflows toward methanol masers suggests that the outflow phase of massive protostars encompasses the methanol maser phase.

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Star formation in the southern dark cloud DC 287.1+02.4

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Aims. We report the discovery of a group of 12 new infrared sources seen toward IRAS 10501-5630 and the southern dark globule DC 287.1+02.4. The globule appears as a round patch of extinction in optical images with a typical diameter of 5 arcmin.
Methods. The sources are seen on Ks and L' band images taken using SOFI at the NTT and ISAAC at the VLT. The globule was mapped in millimeter molecular transitions (CO(1-0), $C^{18}O$(1-0), $C^{18}O$(2-1), CS(2-1), HCN(1-0)) using the SEST telescope.
Results. Millimeter-wave spectroscopy revealed a single dense core seen in $C^{18}O$, CS, and HCN, extending about 2 arcmin. The infrared sources are likely to be embedded in the dense cloud core. The reddest of the new infrared sources, named here DC 287.1+02.4 IRS, is not detected shortward of 2 μm, and it exhibits a very red (Ks $- L'$) colour. The location and colour of this source suggest that this is the near-infrared counterpart of IRAS 10501-5630. Red nebular emission with an elongated shape is also seen in the H and Ks band images and could be due to scattered light originating in the embedded objects.

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Accretion and angular momentum in young low mass stars

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Ph.D degree awarded: June 2006

Two main themes related to low mass stars evolution have been developed in this thesis. On one hand, the evolution of the equatorial rotation velocity, the angular momentum evolution, the behavior of the main X-rays indicators L_X and L_X/L_B; and on the other hand, the gas accretion from the disk to the stellar surface. An emphasis has been given in both cases to the evolution during the post-T Tauri phase between 8 Myr and 30 Myr. Observations were made in order to measure the accretion rate for stars in 9 young open clusters and to measure the photometric rotation periods of some stars in associations. Observations made by other authors were also used, however, for the first time to measure accretion rates.

The main results obtained are: by studying 3 associations with different ages, TW Hya (TWA, 8 Myr), the Beta Pic Moving Group (BPMG, 11 Myr) and the Tucana/Horologium (Tuc/HorA, 30 Myr), we confirmed the presence of a spin up between 8 Myr and 30 Myr, specially for stars with masses from 1.5 to 2.6 $M_{\odot}$, as predicted by theoretical models. We also found that the specific angular momentum is conserved during this time interval. As far as the X-ray indicators are concerned, we show that this radiation is saturated in the younger associations, TWA and BPMG, as is the case in T Tauri stars in the even younger Orion Nebula Cluster (1-3 Myr). We found that desaturation begins to happen only at 30 Myr for G and F type stars with larger masses. This is due to the fact that at this age, the convective layers of these stars attain for the first time their stability (minor size) and this is independent of the high rotations obtained by these stars at this age.

We establish a general angular momentum evolution model, since the T Tauri phase up to the age of the Sun. We considered here the following mechanisms: stellar contraction, star-disk magnetic interaction, differential rotation between the radiative core and the convective envelope and stellar magnetic winds.

To measure accretion we used stellar clusters and associations in order to dispose of all the possible enviroments that could operate and reduce the disks lifetimes. We found that active accretion is present in the associations of the two sub-groups of Sco-Cen, Lower centaurus Crux and Upper Centaurus Lupus, with ages of $\sim$16 Myr. However, accretion at 30 Myr in Horologium is nearly 100 times smaller. The end of the gas in the disks appears then to happen between $\sim$16 and 30 Myr. This result extends, for the first time, the lifetime of the gas in the disks from the value of $\sim$10 Myr commonly presented in the literature. This could be an important fact for theories of giant gas planet formation. We also found that our results from rotation (*spin up*) and from accretion, are compatible with recent models for a rapid final disk gas evaporation in $\sim$100000 yr (UV-Switch). This is produced by a direct ionization radiation from the central star in the last stages of accretion.

http://staff.on.br/gpinzon/w/research.html

Continuum Radiative Transfer in Molecular Cloud Cores

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We present, in this thesis, radiative transfer tools and specific calculations that may help analyse dust thermal emission from prestellar cores in order to probe the physical properties of these objects.
We have developed a three-dimensional Monte-Carlo continuum radiative transfer code for starless molecular cloud cores heated by an external isotropic, or non-isotropic interstellar radiation field. The code computed the dust temperature distribution inside model clouds with specified but arbitrary density profiles. Additionaly, the code can also provide maps of the emergent intensity at different wavelengths and arbitrary viewing angle. Furthermore, in the approximation where the dust temperature is independent of interactions with the gas, and the gas is heated both by collisions with dust grains and ionisation by cosmic rays, the temperature distribution of the gas is also calculated. These results can be compared with observations of specific objects. Such a study was performed to the dark cloud Barnard 68, enabling the derivation of this object's submillimeter and millimeter dust emissivities. We have also computed polarization maps for molecular cloud cores modeled as magnetized singular isothermal toroids, under the assumption that the emitting dust grains are aspherical and aligned with the large-scale magnetic field. The main results of this thesis are:

- cloud models with the physical characteristics typical of dense cores varies monotonically between a minimum at the centre (6-7 K) and a maximum value near the cloud's edge (14-15 K) for the standard ISRF. The decrease of the dust temperature at the cloud centre has the consequence that submillimeter maps sample preferentially the low density envelope of prestellar cores;
- the dust temperaturefor a spherical cloud heated by an external stellar source the temperature profile is non-spherical but the emission profile generally samples the density distribution except at wavelengths shortwards of 100μm;
- the gas and dust temperatures are well coupled for densities larger than 5×10^4 cm^{-3}, and hence the gas temperature decreases with decreasing radius, an effect that may already have been observed for L1544;
- the derived opacity law for Barnard 68 is steeper, but still compatible with $\kappa_\nu \propto \nu^{-2}$.
- the bending of the field lines resulting from the need to counteract the inward pull of gravity naturally produces a depolarization effect toward the centre of the core;
- an outward increasing temperature gradient enhaces the decrease of polarization;
- the presence of a toroidal component of the magnetic field result in higher depolarization and in a larger dispersion in both polarization angles and in polarization degree as a function of intensity.

www.arcetri.astro.it/∼/goncalve/Thesis.pdf

Chemistry in evolving protoplanetary disks

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Ph.D degree awarded: June 2006

Planets form in disks of gas and dust around young stars. Since the gas makes up 99 understanding of planet formation to gain direct information of the gas, independently of what can be learned from dust emission. In this thesis, calculations are presented of the chemistry and gas temperature in disks, and the resulting atomic and molecular emission lines are investigated.

The main focus of the thesis is on the effects of dust settling on gas-phase emission lines of disks around T-Tauri and Herbig Ae stars. It is found that dust settling has little effect on the overall chemistry and molecular lines; the main effect is a decrease in the gas temperature, which is reflected in atomic fine-structure lines and especially in the [O I] lines. The chemistry, and especially the CO abundance and HCN/CN ratio, is affected more by the total gas mass than by the dust gas ratio in a disk.

The models were also applied to the disk around HD 141569A, which is in a transitional stage between a gas-rich Herbig Ae disk and a debris disk. Using chemical models to fit the observed CO rotational lines it is concluded that gas and small dust particles have an approximately interstellar mass ratio, and that gas is still present in the inner hole in the dust distribution.

http://www.strw.leidenuniv.nl/∼jonkheid/thesis

New Jobs

PhD Position on Mid-Infrared Spectroscopy of Protoplanetary Disks

A 4-year PhD (AIO) position is available this fall on a joint project between Prof. E.F. van Dishoeck and Dr. B. Merin at Leiden Observatory and Dr. K.M. Pontoppidan and Prof. G.A. Blake at the California Institute of Technology. The aim of the project is to study the physical and chemical structure of the planet-forming regions of disks around young low-mass T Tauri stars using mid-infrared (3-40 micron) spectra of gaseous (CO, H_2O, CH_4, ...) and solid state features (silicates and ices). The main observational tools will be data obtained with the Spitzer Space Telescope in the context the "Cores to Disks" legacy program and ∼100 hours of approved Cycle 3 programs, as well as future VLT-CRIRES high-resolution spectroscopy. The candidate is also expected to be actively involved in the development and use of radiative transfer models to interpret the data.

The candidate will be located at the California Institute for Technology, USA for the first year, and at Leiden Observatory, the Netherlands for the subsequent three years. The PhD will be awarded at Leiden University.

Applications should include a curriculum vitae (with a list of grades for exams), a brief statement of research experience, and the names of at least two people who can serve as a reference. Selection of candidates will start on August 1 2006 and will continue until the position is filled. The position is open to students of all nationalities with the equivalent of a "doctoraal" (Masters) degree in astronomy, physics or chemistry. The starting date for the position is flexible up to January 1 2007. Please send applications to: Prof. dr. E.F. van Dishoeck, Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands; FAX: +31-71-5275819; e-mail: ewine@strw.leidenuniv.nl.

See http://www.strw.leidenuniv.nl/, http://www.gps.caltech.edu/∼gab/, http://peggysue.as.utexas.edu/SIRTF/ for further information.

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