Abstracts of recently accepted papers

The Brightest OH Maser in the Sky? A Flare of Emission in W75 N

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A flare of maser radio emission in the OH-line 1665 MHz has been discovered in the star forming region W75 N in 2003, with the flux density about 1000 Jy. At the moment of observations this was the strongest OH maser detected during the whole history of studies since the discovery of cosmic masers in 1965. The flare emission is linearly polarized with a degree of polarization near 100%. A weaker flare with a flux of 145 Jy was observed in this source in 2000 – 2001, which was probably a precursor of the powerful flare. Intensity of two other spectral features has decreased after beginning of the flare. Such variation of the intensity of maser condensation emission (increasing of one and decreasing of other) can be explained by passing of the magneto hydrodynamic shock across the regions of the enhanced gas concentration.

Pushing the Envelope: The Impact of an Outflow at the Earliest Stages of Star Formation

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We present new multi-line and 3 mm continuum interferometer observations of the circumstellar environment within 2×10^4 AU of the class 0 protostar IRAS 05295+1247, the source of the RNO 43 outflow. The high-resolution molecular line and continuum images enable a thorough study of the circumstellar envelope, the molecular outflow, and its impact on the surroundings. We detect a highly collimated bipolar molecular outflow seen in the CO(1-0) map, which we interpret to be a new outflow episode, undetected in previous observations of the RNO 43 outflow. The medium-density gas of the outer circumstellar envelope, which is traced by the ^{13}CO(1-0) emission, is accelerated over an extended volume and not confined to the narrow CO outflow axis. Our data also suggest that the outflow affects the chemical composition of the surroundings, enhancing the HCO$^+$(1-0) abundance along its edges. Most importantly, the kinetic energy injected by the outflow is sufficient to produce a velocity gradient in the dense inner circumstellar envelope traced by the C^{18}(1-0) and H^{13}CO$^+$(1-0) emission. Such a strong perturbation to the envelope will clearly have an important effect to the mass-assembling process in IRAS 05295+1247.

The Birth of High Mass Stars: Accretion and/or Mergers?

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The observational consequences of the merger scenario for massive star formation are explored and contrasted with the gradual accumulation of mass by accretion. In high density proto-star clusters, envelopes and disks provide a viscous medium which can dissipate the kinetic energy of passing stars, greatly enhancing the probability of capture. Protostellar mergers may produce high luminosity infrared flares lasting years to centuries followed by a luminosity decline on the Kelvin-Helmholtz time-scale of the merger product. Mergers may be surrounded by thick tori of expanding debris, impulsive wide-angle outflows, and shock induced maser and radio continuum emission. Collision products are expected to have fast stellar rotation and a large multiplicity fraction. Close encounters or mergers will produce circumstellar debris disks with an orientation that differs from that of a pre-existing disk. Thus, massive stars growing by a series of mergers may produce eruptive outflows with random orientations; the walls of the resulting outflow cavities may be observable as filaments of dense gas and dust pointing away from the massive star. The extremely rare merger of two stars close to the upper-mass end of the IMF may be a possible pathway to hypernova generated gamma-ray bursters. In contrast with the violence of merging, the gradual growth of massive stars by accretion is likely to produce less infrared variability, relatively thin circumstellar accretion disks which maintain their orientation, and collimated bipolar outflows which are scaled-up versions of those produced by low-mass young stellar objects. While such accretional growth can lead to the formation of massive stars in isolation or in loose clusters, mergers can only occur in high-density cluster environments. It is proposed that the outflow emerging from the OMC1 core in the Orion molecular cloud was produced by a protostellar merger that released between 10^{48} to 10^{49} ergs less than a thousand years ago.

The chemistry of transient microstructure in the diffuse interstellar medium

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Transient microstructure in the diffuse interstellar medium (ISM) has been observed towards Galactic and extragalactic sources for decades, usually in lines of atoms and ions, and, more recently, in molecular lines. Evidently, there is a molecular component to the transient microstructure. In this paper, we explore the chemistry that may arise in such microstructure. We use a photodissociation region (PDR) code to model the conditions of relatively high density, low temperature, very low visual extinction and very short elapsed time that are appropriate for these objects. We find that there is a well-defined region of parameter space where detectable abundances of molecular species might be found. The best matching models are those where the interstellar microstructure is young (< 100 yr), small (~ 100 AU), and dense ($> 10^4$ cm^{-3}).

A detailed study of the rotating toroids in G31.41+0.31 and G24.78+0.08

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We present the results of high angular resolution millimeter observations of gas and dust toward G31.41+0.31 and G24.78+0.08, two high-mass star forming regions where four rotating massive toroids have been previously detected by Beltrán et al. (2004). The CH$_3$CN (12–11) emission of the toroids in G31.41+0.31 and core A1 in G24.78+0.08 has been modeled assuming that it arises from a disk-like structure seen edge-on, with a radial velocity field. For G31.41+0.31 the model properly fits the data for a velocity $v_{\rm rot} \simeq 1.7$ km s^{-1} at the outer radius $R_{\rm out} \simeq 13400$ AU and an inner radius $R_{\rm inn} \simeq 1340$ AU, while for core A1

in G24.78+0.08 the best fit is obtained for $v_{rot} \simeq 2.0$ km s^{-1} at $R_{out} \simeq 7700$ AU and $R_{inn} \simeq 2300$ AU. Unlike the rotating disks detected around less luminous stars, these toroids are not undergoing Keplerian rotation. From the modeling itself, however, it is not possible to distinguish between constant rotation or constant angular velocity, since both velocity fields suitably fit the data. The best fit models have been computed adopting a temperature gradient of the type $T \propto R^{-3/4}$, with a temperature at the outer radius $T_{out} \simeq 100$ K for both cores. The M_{dyn} needed for equilibrium derived from the models is much smaller than the mass of the cores, suggesting that such toroids are unstable and undergoing gravitational collapse. The collapse is also supported by the CH$_3$^{13}CN or CH$_3$CN line width measured in the cores, which increases toward the center of the toroids. The estimates of v_{inf} and $\dot{M}_{acc}$ are ~ 2 km s^{-1} and $\sim 3 \times 10^{-2}$ $M_\odot$ yr^{-1} for G31.41+0.31, and ~ 1.2 km s^{-1} and $\sim 9 \times 10^{-3}$ $M_\odot$ yr^{-1} for G24.78+0.08 A1. Such large accretion rates could weaken the effect of stellar winds and radiation pressure and allow further accretion on the star. The values of T_{rot} and N_{CH_3CN}, derived by means of the RD method, for both G31.41+0.31 and the sum of cores A1 and A2 (core A of Codella et al. 1997) in G24.78+0.08 are in the range 132–164 K and 2–8×10^{16} cm^{-2}. For G31.41+0.31, the most plausible explanation for the apparent toroidal morphology seen in the lower K transitions of CH$_3$CN (12–11) is self-absorption, which is caused by the high optical depth and temperature gradient in the core.

Chondrule-Forming Shock Fronts in the Solar Nebula: A Possible Unified Scenario for Planet and Chondrite Formation

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Chondrules are mm-sized spherules found throughout primitive, chondritic meteorites. Flash heating by a shock front is the leading explanation of their formation. However, identifying a mechanism for creating shock fronts inside the solar nebula has been difficult. In a gaseous disk capable of forming Jupiter, the disk must have been marginally gravitationally unstable at and beyond Jupiter's orbit. We show that this instability can drive inward spiral shock fronts with shock speeds of up to ~ 10 km s^{-1} at asteroidal orbits, sufficient to account for chondrule formation. Mixing and transport of solids in such a disk, combined with the planet-forming tendencies of gravitational instabilities, results in a unified scenario linking chondrite production with gas giant planet formation.

Large-scale variations of the dust optical properties in the Galaxy

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We present an analysis of the dust optical properties at large scale, for the whole galactic anticenter hemisphere. We used the 2MASS Extended Source Catalog to obtain the total reddening on each galaxy line of sight and we compared this value to the IRAS 100 μm surface brightness converted to extinction by Schlegel et al. (1998). We performed a careful examination and correction of the possible systematic effects resulting from foreground star contamination, redshift contribution and galaxy selection bias. We also evaluated the contribution of dust temperature variations and interstellar clumpiness to our method. The correlation of the near–infrared extinction to the far–infrared optical depth shows a discrepancy for visual extinction greater than 1 mag with a ratio $A_V(\text{FIR})/A_V(\text{gal}) = 1.31 \pm 0.06$. We attribute this result to the presence of fluffy/composite grains characterized by an enhanced far–infrared emissivity. Our analysis, applied to half of the sky, provides new insights on the dust grains nature suggesting fluffy grains are found not only in some very specific regions but in all directions for which the visual extinction reaches about 1 mag.

Diffusion coefficient of a passive contaminant in a local MHD model of a turbulent accretion disc

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We calculate the radial diffusion coefficient for a passive contaminant in an accretion disc which is turbulent due to the action of the magnetorotational instability. Numerical MHD simulations are used to follow the evolution of a local patch of the disc using the shearing box formalism. A separate continuity equation for the mass fraction of contaminant is integrated along with the MHD system, and radial profiles of this fraction are obtained as a function of time. Solutions of a linear diffusion equation are fitted to the numerical measured profiles of the contaminant, treating the diffusion coefficient D as the fitting parameter. At early times, the value of D is found to vary, however once the contaminant is spread over scales comparable to the box size, it saturates at a steady value. The ratio of D to the transport coefficient of angular momentum due to shear stress is small. If D can be used as a proxy for the turbulent magnetic diffusivity, the effective magnetic Prandtl number $P_{\mathrm{eff}} = \nu/D$ (where ν is the coefficient of "effective viscosity" associated with shear stress) would be large.

A study of the Keplerian accretion disk and precessing outflow in the massive protostar IRAS 20126+4104

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We report on interferometric observations at 3.2 and 1.3 mm of the massive young stellar object IRAS 20126+4104 obtained in the $C^{34}S$ and CH_3OH lines and in the continuum emission. The $C^{34}S$ data confirm the existence of a Keplerian disk, as already suggested by various authors. However, the mass of the central object is $\sim 7\ M_{\odot}$, significantly less than previous estimates. We believe that such a discrepancy is due to the fact that the rotation curve is affected not only by the star but also by the mass in the innermost regions of the disk itself: this leads to an overestimate of the stellar mass when low-density tracers are used to study the velocity field over regions larger than a few seconds of arc (i.e. a few 0.01 pc). On the basis of the line profiles we speculate that accretion onto the star might be still occurring through the disk. This seems consistent with current models of high-mass star formation which predict an accretion luminosity equal to that of IRAS 20126+4104 for a $7\ M_{\odot}$ protostar. The CH_3OH lines trace both the disk and the bipolar outflow previously detected in other molecules such as HCO^+, SiO, and H_2. New H_2 images obtained at 2.2 μm confirm that the outflow axis is undergoing precession. We elaborate a simple model that suitably fits the data thus allowing derivation of a few basic parameters of the precession.

AB Aurigae Resolved: Evidence for Spiral Structure

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We obtained high angular resolution (~2″) images of the ^{13}CO(J=1→0) line and 2.7 millimeter continuum emission, and slightly lower resolution images of ^{12}CO(J=1→0) and C^{18}O(J=1→0) line emission toward the Herbig Ae star AB Aurigae. We resolve a circumstellar disk of diameter 780 AU (FWHM) with a velocity pattern consistent with a purely rotational disk at inclination 21.5° and position angle 58.6°. Using Keplerian disk models, we find a central source dynamical mass of 2.8±0.1 M$_\odot$ and a cutoff radius of 615 AU for the ^{13}CO emission. Inclination, mass, and radius determined from ^{12}CO and C^{18}O observations agree with those values, given optical depth and abundance effects. As a result of the high angular resolution of our observations, we confirm the existence of spiral structure suggested by near-IR scattered light images and show that the spiral arms represent density contrasts in the disk.

Atlas and Catalog of Dark Clouds Based on Digitized Sky Survey I

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In this paper, we present a quantitative atlas and catalog of dark clouds derived by using the optical database "Digitized Sky Survey I". Applying a traditional star-count technique to 1043 plates contained in the database, we produced an A_V map covering the entire region in the galactic latitude range $|b| \leq 40°$. The map was drawn at two different angular resolutions of 6′ and 18′, and is shown in detail in a series of figures in this paper. Based on the A_V map, we identified 2448 dark clouds and 2841 clumps located inside them. Physical parameters, such as the position, extent, and optical extinction, were measured for each of the clouds and clumps. We also searched for counterparts among already known dark clouds in the literature. The catalog of dark clouds presented in this paper lists the cloud parameters as well as the counterparts.

Constraining the structure of the non-spherical preprotostellar core L1544

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We present a study of the pre-protostellar core L1544. A series of self-consistent, three-dimensional continuum radiative transfer models are constructed. The outputs of these models are convolved with appropriate telescope beam responses, and compared with existing SCUBA data. The resulting comparison allows us to constrain the structure of L1544. We find that the source is well-fit by a prolate spheroid, having an ellipsoidal power-law density distribution of index $m \sim 2$ ($1.75 < m < 2.25$) in to at least $r \sim 1600$ AU. For $r < 1600$ AU, the data are consistent with either an extension of the power law to smaller radii, or a flattened (Bonner-Ebert like) density distribtion. Furthermore, we find an optical depth along the short axis at 1300μm of $\tau_{1300,\text{short}} = 5 \times 10^{-3}$ ($2 \times 10^{-3} < \tau_{1300,\text{short}} < 8 \times 10^{-3}$), a central luminosity $L_* = 0$ ($< 10^{-3}$ L$_\odot$), a long axis diameter $D = 0.1$ pc ($0.08 < D(\text{pc}) < 0.16$; $16000 < D(\text{AU}) < 32000$), an axis ratio $q = 2$ ($1.7 < q < 2.5$), and an external ISRF defined by Mathis, Mezger, & Panagia (1983) to within 50 per cent. The outer diameter and axis ratio may each be somewhat larger due to potential on-source chopping in the observations, and the projection of the long axis onto the plane of the sky. While these results are similar to those inferred directly from observations or spherical modeling due to the source transparency at submillimeter wavelengths, we infer a smaller size, lower mass, and higher optical depth / column density, exposed to a stronger external radiation field than previously assumed. Finally, we find that both the spectral energy distribution (SED) and surface brightness distribution are necessary to constrain the source properties in this way, and even a modest variation in χ^2 can significantly alter the fit quality.

The Masers Towards IRAS 20126+4104

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We present MERLIN observations of OH, water and methanol masers towards the young high mass stellar object IRAS 20126 + 4104. Emission from the 1665-MHz OH, 22-GHz H_2O and 6.7-GHz CH_3OH masers is detected and all originates very close to the central source. The OH and methanol masers appear to trace part of a circumstellar disk around the central source. The positions and velocities of the OH and CH_3OH masers are consistent with Keplerian rotation around a central mass of $\sim 5M_{\odot}$. The water masers are offset from the OH and CH_3OH masers and have significantly changed since they were last observed, but still appear to be associated to the outflow from the source. All the OH masers components are circularly polarised, in some cases reaching 100 percent while some OH components also have linear polarisation. We identify one Zeeman pair of OH masers and the splitting of this pair indicates a magnetic field of strength $\sim$ 11 mG within $\sim$ 0.5″ (850 AU) of the central source. The OH and CH_3OH maser emission suggest that the disk material is dense, $n > 10^6$ cm^{-3}, and warm, $T > 125$K and the high abundance of CH_3OH required by the maser emission is consistent with the evaporation of the mantles on dust grains in the disk as a result of heating or shocking of the disk material.

Observations of T Tauri Disks at Sub-AU Radii: Implications for Magnetospheric Accretion and Planet Formation

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We determine inner disk sizes and temperatures for four solar-type (1-2 $M_{\odot}$) classical T Tauri stars (AS 207A, V2508 Oph, AS 205A, and PX Vul) using 2.2 μm observations from the Keck Interferometer. Nearly contemporaneous near-IR adaptive optics imaging photometry, optical photometry, and high-dispersion optical spectroscopy are used to distinguish contributions from the inner disks and central stars in the interferometric observations. In addition, the spectroscopic and photometric data provide estimates of stellar properties, mass accretion rates, and disk co-rotation radii. We model our interferometric and photometric data in the context of geometrically flat accretion disk models with inner holes, and flared disks with puffed-up inner walls. Models incorporating puffed-up inner disk walls generally provide better fits to the data, similar to previous results for higher-mass Herbig Ae stars. Our measured inner disk sizes are larger than disk truncation radii predicted by magnetospheric accretion models, with larger discrepancies for sources with higher mass accretion rates. We suggest that our measured sizes correspond to dust sublimation radii, and that optically-thin gaseous material may extend further inward to the magnetospheric truncation radii. Finally, our inner disk measurements constrain the location of terrestrial planet formation as well as potential mechanisms for halting giant planet migration.

Warm gas in the cold diffuse interstellar medium: spectral signatures in the H_2 pure rotational lines

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We present ISO-SWS observations of five pure rotational lines of H_2 along a line of sight through the Galaxy which avoids regions of massive star formation. It samples 30 magnitudes of gas, half of it (*i.e.* 15 magnitudes) being diffuse gas running from the solar neighbourhood to the molecular ring, up to the far side of the Galaxy. The intensities of the S(1) and S(2) lines are too large relative to S(0) to be produced by UV excitation in the known radiation field of the Galaxy. The excitation of these transitions has to tap a more powerful source of energy. We investigate the possibility that it takes place in a large number of magneto-hydrodynamic (MHD) shocks or coherent small-scale vortices, two processes responsible for the intermittent dissipation of MHD turbulence. These dissipation bursts locally and temporarily heat the diffuse gas to temperatures ($T_k \sim 10^3$ K) well above that of the ambient diffuse gas. We compute the spectroscopic signatures of these processes in the H_2 lines. Not only are the computed relative line intensities in good agreement with the observations, but the few percent of warm gas involved is consistent with other independent determinations. We find that the fraction of warm H_2 in the diffuse gas (*i.e.* H_2 molecules in $J_u \geq 3$ levels) on that line of sight, $N(H_2^*)/A_v \approx 4 \times 10^{17} \mathrm{cm}^{-2}\mathrm{mag}^{-1}$, is the same as that found from far UV spectroscopy in the direction of nearby stars. It is also the same as that estimated in the solar neighbourhood to reproduce the large observed abundances of molecules like CH^+. These results suggest that the existence, within the cold neutral medium (CNM), of a few percent of warm gas, for which UV photons cannot be the sole heating source, is ubiquitous and presumably traces the intermittent dissipation of MHD turbulence in the cold diffuse gas.

A survey for Fe 6.4 keV emission in young stellar objects in ρ Oph: the strong fluorescence from Elias 29

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We report the results of a search for 6.4 keV Fe fluorescent emission in Young Stellar Objects (YSOs) with measured accretion luminosities in the ρ Oph cloud, using the existing *Chandra* and XMM-*Newton* observations of the region. A total of nine such YSOs have X-ray data with sufficiently high S/N for the 6.4 keV line to be potentially detected if present. A positive detection of the Fe 6.4 keV line is reported for one object, Elias 29, in both the XMM-*Newton* and the *Chandra* data. The 6.4 keV line is detected in Elias 29 both during quiescent and flaring emission, unlikely all previously reported detections of 6.4 keV Fe fluorescence in YSOs which were made during intense flaring. The observed equivalent width of the fluorescent line is large, at $W_\alpha \simeq 160$ eV, ruling out fluorescence from diffuse circumstellar material. It is also larger than expected for simple reflection from a solar-composition photosphere or circumstellar disk, but it is compatible with being due to fluorescence from a centrally illuminated circumstellar disk. The X-ray spectrum of Elias 29 is also peculiar in terms of its high (ionized) Fe abundance, as evident from the very intense Fe xxv 6.7 keV line emission; we speculate on the possible mechanism leading to the observed high abundance.

A Galactic Plane Relative Extinction Map from 2MASS

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We present three 14400 square degree relative extinction maps of the Galactic Plane ($|b| < 20°$) obtained from 2MASS using

accumulative star counts (Wolf diagrams). This method is independent of the colour of the stars and the variation of extinction with wavelength. Stars were counted in 3.5×3.5 boxes, every $20''$. $1° \times 1°$ surrounding fields were chosen for reference, hence the maps represent local extinction enhancements and ignore any contribution from the ISM or very large clouds. Data reduction was performed on a Beowulf-type cluster (in approximately 120 hours). Such a cluster is ideal for this type of work as areas of the sky can be independently processed in parallel. We studied how extinction depends on wavelength in all of the high extinction regions detected and within selected dark clouds. On average a power law opacity index (β) of 1.0 to 1.8 in the NIR was deduced. The index however differed significantly from region to region and even within individual dark clouds. That said, generally it was found to be constant, or to increase, with wavelength within a particular region.

Relative Evolutionary Time Scale of Hot Molecular Cores with Respect to Ultra Compact HII Regions

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Using the Owens Valley and Nobeyama Radio Observatory interferometers, we carried out an unbiased search for hot molecular cores and ultracompact (UC) HII regions toward the high-mass star forming region G19.61–0.23. In addition, we performed 1.2 mm imaging with SIMBA, and retrieved 3.5 and 2 cm images from the VLA archive data base. The newly obtained 3 mm image brings information on a cluster of high-mass (proto)stars located in the innermost and densest part of the parsec scale clump detected in the 1.2 mm continuum. We identify a total of 10 high-mass young stellar objects: one hot core (HC) and 9 UC HII regions, whose physical parameters are obtained from model fits to their continuum spectra. The ratio between the current and expected final radii of the UC HII regions ranges from 0.3 to 0.9, which leaves the possibility that all O-B stars formed simultaneously. Under the opposite assumption — namely that star formation occurred randomly — we estimate that HC lifetime is less than ~1/3 of that of UC HII regions on the basis of the source number ratio between them.

Dynamical Expansion of Ionization and Dissociation Front around a Massive Star. I. A Mode of Triggered Star Formation

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We analyze the dynamical expansion of the HII region and outer photodissociation region (PDR) around a massive star by solving the UV and FUV radiation transfer and the thermal and chemical processes in a time-dependent hydrodynamics code. We focus on the physical structure of the shell swept up by the shock front (SF) preceding the ionization front (IF). After the IF reaches the initial Strömgren radius, the SF emerges in front of the IF and the geometrically thin shell bounded with the IF and the SF is formed. The gas density inside the shell is about 10-100 times as high as the ambient gas density. Initially the dissociation fronts expands faster than IF and the PDR is formed outside the HII region. Thereafter the IF and SF gradually overtakes the proceeding dissociation fronts (DFs), and eventually DFs are taken in the shell. The chemical composition within the shell is initially atomic, but hydrogen and carbon monoxide molecules are gradually formed. This is partly because the IF and SF overtake DFs and SF enters the molecular region, and partly because the reformation timescales of the molecules become shorter than the dynamical timescale. The gas shell becomes dominated by the molecular gas by the time of gravitational fragmentation, which agrees with some recent observations. A simple estimation of star formation rate in the shell can provide a significant star formation rate in

our galaxy.

Molecular freeze-out as a tracer of the thermal and dynamical evolution of pre- and protostellar cores

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Radiative transfer models of multi-transition observations are used to determine molecular abundances as functions of position in pre- and protostellar cores. The data require a "drop" abundance profile with radius, with high abundances in the outermost regions probed by low excitation 3 mm lines, and much lower abundances at intermediate zones probed by higher frequency lines. The results are illustrated by detailed analysis of CO and HCO^+ lines for a subset of objects. We propose a scenario in which the molecules are frozen out in a region of the envelope where the temperature is low enough ($\lesssim$ 40 K) to prevent immediate desorption, but where the density is high enough ($>10^4$–10^5 cm^{-3}) that the freeze-out timescales are shorter than the lifetime of the core. The size of the freeze-out zone is thereby a record of the thermal and dynamical evolution of the cores. Fits to CO data for a sample of 16 objects indicate that the size of the freeze-out zone decreases significantly between Class 0 and I objects, explaining the variations in, for example, CO abundances with envelope masses. However, the corresponding timescales are $10^{5\pm0.5}$ years, with no significant difference between Class 0 and I objects. These timescales suggest that the dense pre-stellar phase with heavy depletions lasts only a short time, of the order of 10^5 yr, in agreement with recent chemical-dynamical models.

A deep, wide-field search for substellar members in NGC 2264

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We report the first results of our ongoing campaign to discover the first brown dwarfs (BD) in NGC 2264, a young (3 Myr), populous star forming region for which our optical studies have revealed a very high density of potential candidates - 236 in $< 1 \deg^2$ - from the substellar limit down to at least $\sim 20 \, M_{Jup}$ for zero reddening. Candidate BD were first selected using wide field (I, z) band imaging with CFH12K, by reference to current theoretical isochrones. Subsequently, 79 (33%) of the I, z sample were found to have near-infrared 2MASS photometry ($JHK_s \pm 0.3$ mag. or better), yielding dereddened magnitudes and allowing further investigation by comparison with the location of NextGen and DUSTY isochrones in colour-colour and colour-magnitude diagrams involving various combinations of I, J, H and K_s. We discuss the status and potential substellarity of a number of relatively unreddened ($A_v < 5$) likely low-mass members in our sample, but in spite of the depth of our observations in I, z, we are as yet unable to unambiguously identify substellar candidates using only 2MASS data. Nevertheless, there are excellent arguments for considering two faint (observed $I \sim 18.4$ and 21.2) objects as cluster candidates with masses respectively at or rather below the hydrogen burning limit. More current candidates could be proven to be cluster members with masses around $0.1 \, M_\odot$ *via* gravity-sensitive spectroscopy, and deeper near-infrared imaging will surely reveal a hitherto unknown population of young brown dwarfs in this region, accessible to the next generation of deep near-infrared surveys.

Time-series Paschen-β spectroscopy of SU Aurigae

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We present time-series echelle spectra of the Paβ line of the T Tauri star SU Aur, observed over three consecutive nights. The line shows strong variability (~ 10 per cent) over the velocity range (100 km s^{-1}, 420 km s^{-1}) in the red broad absorption component, and weaker variability (~ 2 per cent) over the velocity range (-200 km s^{-1}, 0 km s^{-1}) in the blue wing. The variability in the velocity range (-200 km s^{-1}, 0 km s^{-1}) is correlated with that in (200 km s^{-1}, 400 km s^{-1}), and the variability in these velocity ranges anti-correlates with that in (0 km s^{-1}, 100 km s^{-1}). The mean spectrum from the second night shows a suggestion of a blue-shifted absorption component at about -150 km s^{-1}, similar to that found in the Hα and Hβ lines. We find the position of the subpeak in the red absorption component changes steadily with time, and its motion modulates on half the rotational period. We also find that the modulation of the line equivalent width is associated with a half and a third of the rotational period, which is consistent with the surface Doppler images of SU Aur. Radiative transfer models of a rotationally modulated Paβ line, produced in the shock-heated magnetospheric accretion flow, are also presented. Models with a magnetic dipole offset reproduce the overall characteristics of the observed line variability, including the line equivalent width and the motion of the subpeak in the red absorption trough

Thermal Physics, Cloud Geometry, and the Stellar IMF

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The thermal properties of star-forming clouds have an important influence on how they fragment into stars, and it is suggested in this paper that the low-mass stellar IMF, which appears to be almost universal, is determined largely by the thermal physics of these clouds. In particular, it is suggested that the characteristic stellar mass, a little below one solar mass, is determined

by the transition from an initial cooling phase of collapse to a later phase of slowly rising temperature that occurs when the gas becomes thermally coupled to the dust. Numerical simulations support the hypothesis that the Jeans mass at this transition point plays an important role in determining the peak mass of the IMF. A filamentary geometry may also play a key role in the fragmentation process because the isothermal case is a critical one for the collapse of a cylinder: the collapse and fragmentation of a cylinder can continue freely as long as the temperature continues to decrease, but not if it begins to increase. The limited available results on the dependence of the thermal properties of clouds on metallicity do not suggest a strong dependence of the IMF on metallicity, but the far-infrared background radiation in starburst regions and in the early universe may significantly shift the peak mass to higher masses in these situations.

Triggered Star Formation in the Orion Bright-Rimmed Clouds

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We have developed an empirical and effective set of criteria, based on the 2MASS colors, to select candidate classical T Tauri stars (CTTS). This provides a useful tool to study the young stellar population in star-forming regions. Here we present our analysis of the bright-rimmed clouds (BRCs) B 35, B 30, IC 2118, LDN 1616, LDN 1634, and Orion East to show how massive stars interact with molecular clouds to trigger star formation. Our results support the radiation-driven implosion model in which the ionization fronts from OB stars compress a nearby cloud until the local density exceeds the critical value, thereby inducing the cloud to collapse to form stars. We find that only BRCs associated with strong IRAS $100\,\mu$m emission (tracer of high density) and Hα emission (tracer of ionization fronts) show signs of ongoing star formation. Relevant timescales, including the ages of O stars, expanding H II regions, and the ages of CTTS, are consistent with sequential star formation. We also find that CTTS are only seen between the OB stars and the BRCs, with those closer to the BRCs being progressively younger. There are no CTTS leading the ionization fronts, i.e., within the molecular clouds. All these provide strong evidence of triggered star formation and show the major roles massive stars play in sustaining the star-forming activities in the region.

The newly hatched rich massive cluster in the ridge of the Rosette Molecular Cloud

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We explore loose congregations of medium to high mass proto-clusters identified to the south-east of NGC 2244. Upon using data from the spatially complete 2MASS survey, the true extent of the burst of cluster formation along the ridge of the Rosette Molecular Complex is revealed. Here, we investigate the properties and fine structures of the most prominent cluster embedded in the densest rim of the cloud. This proto-cluster is resolved into two compact sub-clusters aligned along the major axis of the entire complex, in line with NGC 2244. The sub-clusters are found to have a physical scale of around 1 pc, typical of known embedded clusters. The K-band luminosity function also suggests a young age. However, near-infrared excess emission is found in approximately one-sixth of the reddened objects. This is still commensurate with an age estimate of < 1Myr provided the massive stars have rapidly stripped the circumstellar material from their neighbors. The well known massive young binary associated with AFGL 961, however, is situated to the south of the major components of the cluster, where the stellar density is comparatively low. This is inconsistent with mass segregation and signifies a different formation process for these high-mass protostellar objects.

Is the emerging massive cluster NGC 2244 a twin cluster?

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We present in this paper the first near infrared study of the young open cluster NGC 2244, which is well known for its partially embedded nature in the Rosette Nebula. Based on the spatially complete 2 Micron All Sky Survey, the young OB cluster indicates apparent substructures. It is surprisingly resolved into a compact core that matches well the congregation of massive OB stars in the optical, a satellite cluster at a distance of 6.6 pc in its west and probably a major stellar aggregate resembling an arc in structure right below the core. This infrared study provides various new updates on its nature of the young open cluster, including its central position, physical scale and stellar population. A disk fraction of $\sim 20.5\pm2.8\%$ is achieved for its members with masses above 0.8 $M_\odot$. NGC 2244 is hence a unique example for the study of embedded clusters.

Testing the locality of transport in self-gravitating accretion discs - II. The massive disc case

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In this paper, we extend our previous analysis (Lodato & Rice 2004) of the transport properties induced by gravitational instabilities in cooling, gaseous accretion discs to the case where the disc mass is comparable to the central object. In order to do so, we have performed global, three-dimensional smoothed particle hydrodynamics simulations of massive discs. These new simulations show a much more complex temporal evolution with respect to the less massive case. Whereas in the low disc mass case a self-regulated, marginally stable state (characterized by an approximately constant radial profile of the stability parameter Q) is easily established, in the high disc mass case we observe the development of an initial transient and subsequent settling down in a self-regulated state in some simulations, or a series or recurrent spiral episodes, with low azimuthal wave number m, in others. Accretion in this last case can therefore be a highly variable process. On the other hand, we find that the secular evolution of the disc is relatively slow. In fact, the time-average of the stress induced by self-gravity results in accretion time-scales much longer than the dynamical timescale, in contrast with previous isothermal simulations of massive accretion discs. We have also compared the resulting stress tensor with the expectations based on a local theory of transport, finding no significant evidence for global wave energy transport.

The T Tauri Phase Down to Nearly Planetary Masses:
Echelle Spectra of 82 Very Low-Mass Stars and Brown Dwarfs

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Using the largest high-resolution spectroscopic sample to date of young, very low mass stars and brown dwarfs, we investigate disk accretion in objects ranging from just above the hydrogen-burning limit all the way to nearly planetary masses. Our 82 targets span spectral types from M5 to M9.5, or masses from 0.15 $M_\odot$ down to about 15 Jupiters. They are confirmed members of the ρ Ophiuchus, Taurus, Chamaeleon I, IC 348, R Coronae Australis, Upper Scorpius and TW Hydrae star-forming regions and young clusters, with ages from $\lesssim$1 to ~10 Myr. The sample contains 41 brown dwarfs (spectral types $\geq$M6.5). We have previously presented high-resolution optical spectra for roughly half the sample; the rest are new. This is a close to complete

survey of all confirmed brown dwarfs known so far in the regions examined, except in ρ Oph and IC 348 (where we are limited by a combination of extinction and distance). We find that: *(1)* classical T Tauri-like disk-accretion persists in the sub-stellar domain down to nearly the deuterium-burning limit; *(2)* while an Hα 10% width $\geq$ 200 km s^{-1} is our prime accretion diagnostic (following our previous work), permitted emission lines of CaII , OI and HeI are also good accretion indicators, just as in CTTs (we caution against a blind use of Hα width alone, since inclination and rotation effects on the line are especially important at the low accretion rates in these objects); *(3)* the CaII 8662Å line flux is an excellent *quantitative* measure of the accretion rate in very low-mass stars and brown dwarfs (as in higher-mass CTTs), correlating remarkably well with the $\dot{M}$ obtained from veiling and Hα-modeling; *(4)* the accretion rate diminishes rapidly with mass – our measurements support previous suggestions that $\dot{M}$ $\propto$ $\mathcal{M}_*^2$ (albeit with considerable scatter), and extend this correlation to the entire range of sub-stellar masses; *(5)* the fraction of very low-mass stellar and brown dwarf accretors decreases substantially with age, as in higher-mass stars; *(6)* at any given age, the fraction of very low-mass stellar and substellar accretors is comparable to the accretor fraction in higher-mass stars; and *(7)* a number of our sources with infrared excesses arising from dusty disks do not evince measurable accretion signatures, with the incidence of such a mismatch increasing with age: this implies that disks in the low mass regime can persist beyond the main accretion phase, and parallels the transition from the classical to post-T Tauri stage in more massive stars. These strong similarities at young ages, between higher-mass stars and low-mass bodies close to and below the hydrogen-burning limit, are consistent with a common formation mechanism in the two mass regimes.

The near-infrared size-luminosity relations for Herbig Ae/Be disks

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We report the results of a sensitive K-band survey of Herbig Ae/Be disk sizes using the 85-m baseline Keck Interferometer. Targets were chosen to span the maximum range of stellar properties to probe the disk size dependence on luminosity and effective temperature. For most targets, the measured near-infrared sizes (ranging from 0.2 to 4 AU) support a simple disk model possessing a central optically-thin (dust-free) cavity, ringed by hot dust emitting at the expected sublimation temperatures (T_s ~1000-1500K). Furthermore, we find a tight correlation of disk size with source luminosity $R \propto L^{\frac{1}{2}}$ for Ae and late Be systems (valid over more than 2 decades in luminosity), confirming earlier suggestions based on lower-quality data. Interestingly, the inferred dust-free inner cavities of the highest luminosity sources (Herbig B0-B3 stars) are *under-sized* compared to predictions of the "optically-thin cavity" model, likely due to optically-thick gas within the inner AU.

Measuring Accretion in Young Substellar Objects: Approaching the Planetary Mass Regime

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We present observations of Hα emission line profiles taken at Magellan Observatory for a sample of 39 young low-mass stars and brown dwarfs in the Taurus and Chamaeleon I star forming regions. We have identified 11 new substellar accretors, more than tripling the number of known brown dwarfs with measurable accretion activity. These include the lowest-mass objects yet seen with accretion, with masses down to ~ 0.015 M$_\odot$. Using models of Hα emission produced in magnetospheric accretion flows, the most widely applicable primary calibrator now available, we determine the first estimates of mass accretion rates for objects at such extremely low masses. For the six objects with masses < 0.03 M$_\odot$, we find accretion rates of $\sim 5 \times 10^{-12}$ M$_\odot$yr^{-1}, among the smallest yet measured. These new results continue the trend of decreasing mass accretion rate with decreasing (sub)stellar mass that we have noted previously for samples of more massive objects; the overall correlation is $\dot{M} \propto$ M$^{2.1}$, and now extends over a mass range of over two orders of magnitude. Finally, the absence of a discontinuity in the distribution of accretion rates with mass tends to suggest that stars and brown dwarfs share similar formation histories.

The Outburst of V1647 Orionis Revealed by *Spitzer*

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We present *Spitzer* Space Telescope observations of V1647 Ori, the outbursting source lighting McNeil's nebula, taken near the optical peak of the outburst in early March 2004. The source is easily detected in all *Spitzer* imaging bands from 3.6 - 70 μm. The fluxes at all wavelengths are roughly a factor of 15 brighter than pre-outburst levels; we measure a bolometric luminosity of 44 $L_\odot$. We posit that this event is due to an increase in the accretion luminosity of the source. Simple models of an accretion disk plus tenuous envelope can qualitatively explain the observed pre- and post-outburst spectral energy distributions. The accretion activity implied by our results indicates that the outburst may be intermediate between FUor and EXor-type events. We also report the discovery of a previously unknown mid-infrared counterpart to the nearby Herbig-Haro object HH 22.

Circumstellar discs around solar-mass stars in NGC 6611

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We have performed $IZJHKL'$ observations in NGC 6611, the young cluster that ionises the Eagle Nebula. We have discovered a rich pre-main sequence concentrated around the O-stars in the cluster. As measured by their L$'$-band excesses, at least $58\% \pm 5\%$ of the pre-main sequence objects (0.45 M$_\odot$ $<$ M $<$ 2 M$_\odot$) have circumstellar discs. By comparing this disc frequency with frequencies determined for regions where the pre-main sequence stars are subject to less ionising radiation, we find no evidence that the harsher environment of NGC 6611 (approximately an order of magnitude more ionising Lyman continuum radiation than the Trapezium cluster) significantly hastens the dissipation of circumstellar discs around solar-mass stars.

A Solution to the Pre–Main–Sequence Accretion Problem

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Accretion rates of order 10^{-8} M$_\odot$yr^{-1} are observed in young pre–main–sequence (PMS) stars of approximately a solar mass with evidence of circumstellar disks. The accretion rate is significantly lower for PMS stars of smaller mass, approximately proportional to the second power of the stellar mass, $\dot{M}_{accr} \propto M^2$. The traditional view is that the observed accretion is the consequence of the angular momentum transport in isolated circumstellar disks, controlled by disk turbulence or self–gravity. However, these processes are not well understood and the observed accretion, a fundamental aspect of star formation, remains an unsolved problem. In this Letter we propose the stellar accretion rate is controlled by accretion from the large scale gas distribution in the parent cloud, not by the isolated disk evolution. Approximating this process as Bondi–Hoyle accretion onto the star–disk system, we obtain accretion rates comparable to the observed ones. We also reproduce the observed dependence of the accretion rate on the stellar mass. These results are based on realistic values of the ambient gas density and velocity, as inferred from numerical simulations of star formation in self–gravitating turbulent clouds.

Pulsating young brown dwarfs

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We present the results of a nonadiabatic, linear stability analysis of models of very low-mass stars (VLMSs) and brown dwarfs (BDs) during the deuterium burning phase in the center. We find unstable fundamental modes with periods varying between ~5 hr for a 0.1 M$_\odot$ star and ~1 hr for a 0.02 M$_\odot$ BD. The growth time of the instability decreases with decreasing mass and remains well below the deuterium burning time scale in the mass range considered (0.1–0.02 M$_\odot$). These results are robust against variations of the relevant input physics in the evolutionary models. We identify possible candidates for pulsational variability among known VLMSs and BDs in nearby star forming regions whose location in the HR diagram falls within or close to the boundary of the instability strip. Finally, we discuss the possibility that the variability observed in a few objects with periods of ~1 hr can be interpreted in terms of pulsation.

Giant Planet Formation: A First Classification of Isothermal Protoplanetary Equilibria

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We present a model for the equilibrium of solid planetary cores embedded in a gaseous nebula. From this model we are able to extract an idealized roadmap of all hydrostatic states of the isothermal protoplanets. The complete classification of the isothermal protoplanetary equilibria should improve the understanding of the general problem of giant planet formation, within the framework of the nucleated instability hypothesis. We approximate the protoplanet as a spherically symmetric, isothermal, self-gravitating classical ideal gas envelope in equilibrium, around a rigid body of given mass and density, with the gaseous envelope required to fill the Hill-sphere. Starting only with a core of given mass and an envelope gas density at the core surface, the equilibria are calculated without prescribing the total protoplanetary mass or nebula density. The static critical core masses of the protoplanets for the typical orbits of 1, 5.2, and 30 AU, around a parent star of 1 solar mass are found to be 0.1524, 0.0948, and 0.0335 Earth masses, respectively, for standard nebula conditions (Kusaka et al. 1970). These values are much lower than currently admitted ones primarily because our model is isothermal and the envelope is in thermal equilibrium with the nebula. For a given core, multiple solutions (at least two) are found to fit into the same nebula. We extend the concept of the static critical core mass to the local and global critical core mass. We conclude that the 'global static critical core mass' marks the meeting point of all four qualitatively different envelope regions.

Are PAHs precursors of small hydrocarbons in Photo–Dissociation Regions? The Horsehead case

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We present maps at high spatial and spectral resolution in emission lines of CCH, c-C_3H_2, C_4H, ^{12}CO and $C^{18}O$ of the edge of the Horsehead nebula obtained with the Plateau de Bure Interferometer (PdBI). The edge of the Horsehead nebula is a one-dimensional Photo–Dissociation Region (PDR) viewed almost edge-on. All hydrocarbons are detected at high signal–to–noise ratio in the PDR where intense emission is seen both in the H_2 ro-vibrational lines and in the PAH mid–infrared bands. $C^{18}O$ peaks farther away from the cloud edge. Our observations demonstrate that CCH, c-C_3H_2 and C_4H are present in UV–irradiated molecular gas, with abundances nearly as high as in dense, well–shielded molecular cores.
PDR models *i)* need a large density gradient at the PDR edge to correctly reproduce the offset between the hydrocarbons and H_2 peaks and *ii)* fail to reproduce the hydrocarbon abundances. We propose that a new formation path of carbon chains, in addition to gas phase chemistry, should be considered in PDRs: because of intense UV–irradiation, large aromatic molecules and small carbon grains may fragment and feed the interstellar medium with small carbon clusters and molecules in significant amounts.

Circumstellar and Circumbinary Disks in Eccentric Stellar Binaries

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We explore test particle orbits in the orbital plane of eccentric stellar binary systems, searching for "invariant loops": closed curves that change shape periodically as a function of binary orbital phase as the test particles in them move under the stars' gravity. Stable invariant loops play the same role in this periodically-varying potential as stable periodic orbits do in stationary potentials; in particular, when dissipation is weak, gas will most likely follow the non-intersecting loops, while nearby particle orbits librate around them. We use this method to set bounds on the sizes of disks around the stars, and on the gap between those and the inner edge of a possible circumbinary disk. Gas dynamics may impose further restrictions, but our study sets upper bounds for the size of circumstellar disks, and a lower bound for the inner radius of a circumbinary disk. We find that circumstellar disks are sharply reduced as the binary's eccentricity grows. For the disk around the secondary star, the tidal (Jacobi) radius calculated for circular orbits at the periastron radius, gives a good estimate of the maximum size. Disks change in size and shape only marginally with the binary phase, with no strong preference to increase or decrease at any particular phase. The circumstellar disks in particular can be quite asymmetric. We compare our results with other numerical and theoretical results and with observations of the α Centauri and L1551 systems, finding very good agreement. The calculated changes in the shapes and crowding of the circumstellar orbits can be used to predict how the disk luminosity and mass inflow should vary with binary phase.

Projection of circumstellar disks on their environments

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We use a 3D Monte Carlo radiative transfer code to study the projection of large shadows by circumstellar disks around young stellar objects on surrounding reflection nebulosity. It is shown that for a wide range of parameters a small (10-100 AU) circumstellar disk can project a large (1 000-10 000 AU) dark band in the near-infrared that often resembles a massive edge-on disk. The disk shadows are divided into two basic types, depending on the distribution of the reflecting material and the resulting morphology of the shadows in the near-infrared. Two YSOs associated with bipolar nebulosity, CK 3/EC 82 illuminating the Serpens Reflection Nebula (SRN) and Ced 110 IRS 4 in the Chamaeleon I molecular cloud, are modelled in detail as disk shadows. Spectral energy distributions of the two sources are collected using both archival ISO data and new Spitzer-IRS data. An axisymmetric model consisting of a small disk and a spherically symmetric envelope can reproduce the near-infrared images and full spectral energy distributions of the two disk shadow candidates. It is shown that the model fits can be used to constrain the geometry of the central disks due to the magnifying effect of the projection. The presence of a disk shadow may break a number of degeneracies encountered when fitting to the SED only. Specifically, the inclination, flaring properties and extinction toward the central star may be independently determined from near-infrared images of disk shadows. Constraints on the disk mass and size can be extracted from a simultaneous fit of SEDs and images. We find that the CK 3 disk must have a very low mass in opacity-producing, small ($\lesssim 10\,\mu$m) dust grains (corresponding to a total mass of $\sim 7 \times 10^{-6}\,M_\odot$, assuming a gas-to-dust ratio of 100) to simultaneously reproduce the very strong silicate emission features and the near-infrared edge-on morphology. Ced 110 IRS 4 requires that a roughly spherical cavity with radius ~ 500 AU centered on the central star-disk system is carved out of the envelope to reproduce the near-infrared images. We show that in some cases the bipolar nebulosity created by a disk shadow may resemble the effect of a physical bipolar cavity where none exists. We find that a disk unresolved in near-infrared images, but casting a large disk shadow, can be modelled at a level of sophistication approaching that of an edge-on disk with resolved near-infrared images. Selection criteria are given for distinguishing disk shadows from genuine large disks. It is found that the most obvious observable difference between a disk shadow and a large optically thick disk is that the disk shadows have a compact near-infrared source near the center of the dark band. High resolution imaging and/or polarimetry should reveal the compact source in the center of a disk shadow as an edge-on disk. Finally, it is shown that disk shadows can be used to select edge-on disks suitable for observing ices located inside the disk.

IRAS 16293-2422B: A Compact, Possibly Isolated Protoplanetary Disk in a Class 0 Object

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Theoretical arguments suggest that protoplanetary disks around young stars should start small and grow with the addition of high angular momentum material to reach the radii of several hundred AUs that characterize the disks around optically visible T Tauri stars. Examples of much more compact disks, with radii much less than 100 AU, have been found around some very young stars, but in all cases tidal truncation from a near binary companion provides a ready explanation for the small disk size. We report here an example of a compact, possibly isolated disk around the class 0 object IRAS16293-2422B, which is thought to be among the youngest protostars known. This disk has a Gaussian half power radius of only ~8 AU, and a detailed, self-consistent, accretion disk model indicates an outer radius of only 26 AU. This discovery supports the notion that protoplanetary disks start small and grow with time, although other explanations for the compact size cannot be ruled out, including gravitational instability in its outer parts and tidal truncation from the close approach of a now distant stellar companion.

A Simple Model for H_2 Line Profiles in Bow Shocks

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We present a model for empirically reproducing line profiles of molecular hydrogen emission in bow shocks. The model takes into account bow velocity, dissociation limit, a cooling function, viewing angle, bow shape and a limited form of extinction. Our results show that both geometrical factors and shock physics can significantly affect the profile morphology. In a companion paper we will apply this model to Fabry-Perot observations of bow shocks in the Orion BN-KL outflow.

Emission-line profile modelling of structured T Tauri magnetospheres

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We present hydrogen emission line profile models of magnetospheric accretion onto Classical T Tauri stars. The models are computed under the Sobolev approximation using the three-dimensional Monte Carlo radiative-transfer code TORUS. We have calculated four illustrative models in which the accretion flows are confined to azimuthal curtains – a geometry predicted by magneto-hydrodynamical simulations. Properties of the line profile variability of our models are discussed, with reference to dynamic spectra and cross-correlation images. We find that some gross characteristics of observed line profile variability are reproduced by our models, although in general the level of variability predicted is larger than that observed. We conclude that this excessive variability probably excludes dynamical simulations that predict accretion flows with low degrees of axisymmetry.

T Tauri stellar magnetic fields: He I measurements

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We present measurements of the longitudinal magnetic field in the circumstellar environment of seven classical T Tauri stars. The measurements are based on high-resolution circular spectropolarimetry of the He I λ5876 emission line, which is thought to form in accretion streams controlled by a stellar magnetosphere. We detect magnetic fields in BP Tau, DF Tau and DN Tau, and detect statistically significant fields in GM Aur and RW Aur A at one epoch but not at others. We detect no field for DG Tau and GG Tau, with the caveat that these objects were observed at one epoch only. Our measurements for BP Tau and DF Tau are consistent, both in terms of sign and magnitude, with previous studies, suggesting that the characteristics of T Tauri magnetospheres are persistent over several years. We observed the magnetic field of BP Tau to decline monotonically over three nights, and have detected a peak field of 4 kG in this object, the highest magnetic field yet observed in a T Tauri star. We combine our observations with results from the literature in order to perform a statistical analysis of the magnetospheric fields in BP Tau and DF Tau. Assuming a dipolar field, we determine a polar field of $\sim$ 3 kG and a dipole offset of 40° for BP Tau, while DF Tau's field is consistent with a polar field of $\sim$ -4.5 kG and a dipole offset of 10°. We conclude that many classical T Tauri stars have circumstellar magnetic fields that are both strong enough and sufficiently globally-ordered to sustain large-scale magnetospheric accretion flows.

On the number and lifetime of 6.7 GHz methanol masers

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A statistical estimate of the number of 6.7 GHz methanol masers in the Milky Way and their lifetime is presented. The estimate is based on the currently known number of masers, a realistic correction for sensitivity effects and generally accepted galactic star formation rates and initial mass functions. The analysis suggests that the minimum number of masers in the Galaxy is on the order of 850 while a more realistic estimate of total number of masers is on the order of 1200 ± 84. The lifetime is estimated to be between 2.5×10^4 and 4.5×10^4 years, with the variation being due to the use of different initial mass functions. The estimated lifetime agrees with that found from independent studies and agrees remarkably well with the time scale for the chemical evolution of methanol in hot cores as well as with the dynamical time scales of molecular outflows associated with high mass star formation regions. It is shown that the hypothesis of the masers being associated with propagating planar shocks in cores or clumps results in lifetimes for the masers that are smaller by a factor of two or more compared to the lifetime of methanol masers as estimated here.

Multi-epoch infrared photometry of the star forming region G173.58+2.45

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We present a multi-epoch infrared photometric study of the intermediate-mass star forming region G173.58+2.45. Photometric observations are obtained using the near-infrared $JHKL'M'$ filters and narrow-band filters centered at the wavelengths of H_2 (1-0) S(1) (2.122 μm) and [FeII] (1.644 μm) lines. The H_2 image shows molecular emission from shocked gas, implying the presence of multiple star formation and associated outflow activity. We see evidence for several collimated outflows. The most extended jet is at least 0.25 pc in length and has a collimation factor of $\sim$ 10, which may be associated with a binary system within the central cluster, resolved for the first time here. This outflow is found to be episodic; probably occurring or getting enhanced during the periastron passage of the binary. We also find that the variable star in the vicinity of the outflow source, which was known as a FU Ori type star, is probably not a FU Ori object. However, it does drive a spectacular outflow and the variability is likely to be related to accretion, when large clouds of gas and dust spiral in towards the central source. Many other

convincing accretion-outflow systems and YSO candidates are discovered in the field.

Deep Imaging Surveys of Star-Forming Clouds III.
Herbig-Haro Objects in the Perseus Molecular Cloud

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We present a catalog of 72 new Herbig-Haro (HH) objects discovered in the Perseus molecular cloud. There are 69 previously cataloged HH objects in this region, the new discoveries bring the total number of known HH objects in Perseus to 141. Individual outflows often contain several distinct HH objects. These observations demonstrate that the Perseus Molecular Cloud is one of the most active star forming regions in the solar vicinity. We explore different methods for probing the momentum injection rate of outflows and examine whether outflows can drive turbulence within the molecular cloud. On the scale of the entire Perseus cloud, the shocks produced by outflows from young stars may not inject momentum at a sufficient rate to counter the rate at which momentum decays. However, intense outflow activity within individual cloud cores with high star formation rates, such as NGC 1333, may be sufficient to locally support or even disrupt the core.

The circumstellar environments of high-mass protostellar objects
II. Dust continuum models

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We analyse the dust continuum emission seen towards a sample of candidate high-mass protostellar objects, modelling the cores we recently observed at 850 μm with a one-dimensional radiative transfer code. Fitting radial slices in a range of directions across sources, we identify a number of objects that have non-spherical density profiles and show that for such sources fitting the azimuthal averaged emission produces erroneous estimates of the source properties. We find the majority of cores can be successfully modelled using envelopes of power-law density structure (where $\rho \propto r^{-\alpha}$), finding a mean power-law index of $\overline{\alpha} = 1.3 \pm 0.4$. These envelopes extend considerably further, are more dense, and have a more shallow density profile than those bearing low-mass protostars. The majority of best-fit models have an SED resembling the cold-component dust bodies previously proposed for the sample, implying the short wavelength emission seen towards the HMPOs either originates from a separate hot dust component(s), or involves mechanisms such as accretion disks, stochastic heating and/or optically thin cavities not included in the radiative transfer model. We find evidence of smaller dust-free cavities towards some pre-UCHII sources. The modelling indicates a correlation between α and optical depth, suggesting that the densest cores also tend to have the most strongly peaked power-law density profiles.

Proper Motion of the Irradiated Jet HH 399 in the Trifid Nebula

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HH 399 is one of the first Herbig Haro flows recognized to be irradiated by the UV radiation of the massive O7.5 star in the Trifid nebula. We present the proper motion of the first irradiated jet based on two epochs of HST observations of HH 399 separated nearly by five years using Hα and [SII] line filters. High proper motion with continuous velocities between 200±55 and 528±24 km/s are detected in both lines along the $18''$ extent of the jet axis. The irradiated fully-ionized jet consists of numerous knots along the jet but also shows the evidence for a number of isolated blob-like structures running immediately outside the jet with lower transverse velocities. The transverse velocities combined with radial velocity measurements indicate that the jet axis lies away from the plane of the sky by only few degrees. We argue that the jet is fully ionized based on [SII]/Hα line ratio as well as radio continuum emission detected from the full extent of the jet at 3.6cm wavelength. The stellar mass-loss rate producing HH 399 is estimated to be $\approx 2 \times 10^{-6}$ M$_\odot$ yr^{-1}.

Search for CO Outflows toward a Sample of 69 High-Mass Protostellar Candidates II: Outflow Properties

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We present a study of molecular outflows toward a sample of 69 luminous IRAS point sources. The sample is associated with dense molecular gas and has far infrared luminosities ranging from 10^2 to 10^5 L$_\odot$, indicating these objects as regions likely forming high-mass stars. Mapping in the CO J=2-1 line shows that molecular outflows are ubiquitous in these regions. Most of the outflows have masses of tens of L$_\odot$. The typical dynamical timescale of the flow, without correcting for inclination of the flow axis, is a few $\times 10^4$ yrs. The typical energy in the outflows is 10^{46} erg, comparable to the turbulent energy in the core.

Nearly half of the outflows show spatially resolved bipolar lobes. This indicates that low-mass young stars that coexist in the region are not responsible for the bipolar outflows observed. It is the more massive stars that drive the outflow. The large detection rate of outflows in the region favors an accretion process in the formation of massive stars.

The maximum mass loss rate in the wind is about 10^{-4} L$_\odot$ yr^{-1}. If these outflows are driven via accretion, the accretion rate should be as high as a few times 10^{-4} L$_\odot$ yr^{-1}. We compare CO outflows with images at near infrared wavelengths from the 2MASS archive, and find that some outflows are associated with extended emission in the K-band, which may be partly due to vibrationally excited H$_2$ emission at 2.12 μm.

Abstracts of recently accepted major reviews

Precursors of UCHɪɪ regions & the evolution of massive outflows

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Since this contributions was meant to cover two subjects which are both in the field of massive star formation but which in its details can be discussed separately, this paper is divided in two sections. First, we present characteristics of precursors of UCHɪɪ regions and their likely evolutionary properties. The second section discusses massive molecular outflows, their implications for high-mass star formation, and a possible evolutionary sequence for massive outflows.

Accepted by the proceedings of the "Cores to Clusters" meeting in Porto/Portugal October 2004

Preprints available at http://cfa-www.harvard.edu/~hbeuther/

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter.

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

Dissertation Abstracts

Dynamical Masses of Pre-Main Sequence Stars

Gail H. Schaefer

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Electronic mail: gschaefer@stsci.edu

Ph.D dissertation directed by: Michal Simon

Ph.D degree awarded: December 2004

Determining precise masses of pre-main sequence stars is important for understanding the physical processes of star formation. The goal of my thesis is to contribute to the set of known dynamical masses of young stars. Emphasis is placed on masses below 1 $M_\odot$, where few reliable measurements are available and theoretical tracks of stellar evolution are particularly discrepant. To this effect, I have used a variety of high spatial and spectral resolution techniques to measure the orbital motion in binary and triple star systems and to map the rotation of circumstellar disks around single stars. The instrumentation that can spatially resolve short period binaries at the distance of the Taurus and Ophiuchus star forming regions has only recently become available. Most of the multiple systems that I have been monitoring astrometrically have expected periods longer than 20 years. Through analysis of the astrometric orbits, I find that even if the complete orbit of a binary is not well-determined, the measurements can yield a useful value for the total mass of the system. I derive preliminary values for the total mass in the binaries DF Tau ($0.78^{+0.26}_{-0.14}$ $M_\odot$), ZZ Tau, ($0.68^{+0.18}_{-0.14}$ $M_\odot$), Elias 12 Na-Nb ($0.97^{+0.83}_{-0.36}$ $M_\odot$), and T Tau Sa-Sb ($4.7^{+2.4}_{-1.8}$ $M_\odot$), assuming a fiducial distance of 140 pc. I also present infrared spectroscopic observations for these systems, with likely radial velocity detections for both components in DF Tau and V853 Oph A. Because the velocities of these long period systems vary slowly, these measurements could potentially provide data for a future determination of the mass ratio. More recently, I present the first angularly resolved measurement of the projected separation of the double-lined spectroscopic binary, Haro 1-14c, using long baseline interferometry. With a period of 591 days, the measurement of the individual component masses, as well as the distance to the system, will be attained with continued observations over the next few years. By mapping the rotation of circumstellar disks in CO emission, I derive preliminary stellar masses for IRAS 04385+2550 (0.42±0.14 $M_\odot$) and LkHα 358 (0.34±0.12 $M_\odot$), at an assumed distance of 140 pc. Confusion with the parent molecular cloud is the main limitation to the precision of the derived masses. From a sample of T Tauri stars observed in 1 mm continuum emission, I find that low-mass stars tend to have less massive disks, with upper limits on the continuum flux densities of < 20 mJy for masses below ∼ 0.5 $M_\odot$. Even though there are observational challenges to measuring reliable masses of young stars, current and future advances in the field of high spatial resolution instrumentation will provide access to a larger sample of pre-main sequence stars where dynamical mass measurements are possible.

New Jobs

Postdoctoral Fellowships and Studentships in Understanding Jets from Young Stars

As part of the Marie Curie Research Training Network Programme, the European Commission has recently provided funding for a new network called JETSET. The network will bring together researchers working on observations, theory, computational modeling (including grid computing) and laboratory experiments centred on understanding outflows from young stars. Applications are now invited for 6 Postdoctoral Fellowships and 11 PhD Studentships in these fields

The network links the following eleven institutions:

1. Dublin Institute for Advanced Studies, Ireland (**The Co-ordinating Institution**)

2. Università degli Studi di Torino, Italy

3. Universite Joseph Fourier, Grenoble, France

4. Institute of Accelerating Systems and Applications, University of Athens, Greece

5. Observatoire de Paris, France

6. Osservatorio Astronomico di Roma, Italy

7. Osservatorio Astrofisico di Arcetri, Florence, Italy

8. Thüringer Landessternwarte, Tautenburg, Germany

9. Centro de Astrofisica da Universidade do Porto, Portugal

10. Landessternwarte Heidelberg, Germany

11. Imperial College of Science, Technology and Medicine, London, UK

Posts (Fellowships and Studentships) will be available in the following areas:

1. Models of MHD Jets in Young Stars: 2 Fellowships in Athens and Grenoble, 2 Studentships in Porto and Turin

2. The Observed Structure and Propagation of Stellar Jets: 1 Fellowship in Florence and 3 Studentships in Turin, Porto and Grenoble

3. The Molecular Counterparts and Effects of Jets on their Environment: 1 Fellowship in Tautenburg and 2 Studentships in Rome

4. The Structure and Propagation of Laboratory Jets: 2 Studentships in London

5. Large Numerical Simulations of Jets using Grid Technology: 1 Fellowship in Dublin and 2 Studentships in Heidelberg

6. Global Approach: 1 Fellowship in Dublin

Individual deadlines for applications are posted on the JETSET website (**www.jetsets.org**) where further details about the positions, application procedures and restrictions may be found. All candidates will be required to submit a curriculum vitae, a short research proposal (not for studentships) and three letters of reference. JETSET is committed to equal opportunity/affirmative action. Women and members of minorities are encouraged to apply.

Staff Position in Star Formation Research at CEA/Saclay, France

The Astrophysics Department of CEA Saclay seeks candidates for a permanent staff position in star and/or planet formation research.

The Astrophysics Department ("Service d'Astrophysique") at CEA Saclay is a major space astrophysics laboratory, located about 20 km south-west of Paris, close to several other astronomy centers. In particular, the department built the ISOCAM mid-infrared camera aboard *ISO*, and is actively involved in the development of the two far-infrared and submillimeter imaging instruments PACS and SPIRE of the future *Herschel* Space Observatory (*HSO*) to be launched by ESA at the end of 2007. The department has also been responsible for instruments on the ground, such as the VLT Imager and Spectrometer for the mid-Infrared (VISIR). As such, we benefit from a large amount of guaranteed time observations with both *Herschel* and VISIR.

The Saclay Star Formation group has been engaged for a long time in multi-wavelength studies of the stellar and gas/dust content of nearby molecular clouds, from the radio to the X-ray range. In recent years, our group has focused on millimeter/submillimeter studies of the earliest stages of star formation including protostars and pre-collapse cloud cores, and on infrared imaging of dusty disks around young stars. Various instruments are being routinely used such as the IRAM 30m telescope and Plateau de Bure interferometer, and the ESO telescopes. We are also involved in hydrodynamical simulations of cloud fragmentation and collapse. We seek candidates wishing to work in one of these areas.

The successful applicant is expected to carry out independent research projects and to take an active role in the scientific exploitation of the major VISIR and *Herschel* observing programmes in which our group is involved.

We invite applications from scientists with a PhD in astrophysics and a strong observational or theoretical record in the field of molecular clouds, young stellar objects, or circumstellar disks. Demonstrated experience in either dust/gas radiative transfer modelling or submillimeter instrumentation will be a key advantage. The position will be filled at the equivalent of tenure-track or, for an exceptional candidate, tenured level. The starting date is flexible and could be as early as 1 September 2005.

Please send a CV, a list of publications and a statement of research interests, and arrange for three letters of recommendation before 31 March 2005. Later applications will be considered until the position is filled. Informal inquiries are welcome.

Attention: Dr. Philippe André, CEA Saclay, DSM/DAPNIA Service d'Astrophysique,
Orme des Merisiers - Bât. 709, F-91191 Gif-sur-Yvette Cedex, France
(Phone: + 33 1 69 08 92 65; FAX: + 33 1 69 08 65 77; E-mail: pandre@cea.fr)

Moving ... ??

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

Postdoctoral Fellow (Circumstellar Matter) at the Space Telescope Science Institute

Applications are invited for a postdoctoral research position at the Space Telescope Science Institute starting as early as summer 2005. The successful applicant will work with Dr. Margaret Meixner and collaborators on studies of circumstellar dust shells found around main sequence stars, pre-main sequence stars, supernovae and evolved stars. This research will involve observations with HST, Spitzer, and ground based facilities. Independent research in related areas will be supported and encouraged. Research experience in the areas of planet formation, star formation, supernovae, evolved stars, dust or radiative transfer is desirable. A PhD in astronomy or astrophysics is required.

The position is for two years, with a possible renewal for a third year. STScI, located on Johns Hopkins University Campus in Baltimore, Maryland, offers an excellent benefit package, competitive salaries, and a stimulating work environment.

Applicants should send a cover letter with position applying for, curriculum vitae, list of publications, and a brief statement of research interests, accomplishments, and relevant technical expertise to the address below:

Space Telescope Science Institute
ATTN: Human Resources, Req 428
3700 San Martin Drive
Baltimore, MD 21218, USA

They should also arrange for three letters of recommendation to be sent directly to the same address. Completed applications received by March 1, 2005 are assured of full consideration. Women and members of minority groups are strongly encouraged to apply. EOE/AA/M/F/D/V

Inquires regarding this position can be submitted to: meixner@stsci.edu

Short Announcements

On January 9, 2005 it was announced in IAU Circular No. 8460 that the EXor V1118 Ori has gone into outburst, brightening for the first time since 1997 to V = 14.0 from its usual magnitude near mag 18. No further information is available, but if the star is still bright it would be valuable to monitor its decay photometrically and spectroscopically.

Meetings

Kobe International School of Planetary Sciences 2005:

"ORIGIN OF PLANETARY SYSTEMS"

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Kobe International School of Planetary Sciences 2005 will be held at Awaji Island in Japan, from July 11 through July 17, 2005. This school aims to promote lively international interaction in planetary science and to educate graduate students and young researchers from all over the world.

This international school is held annually, and this year, the focus will be on the "Origin of Planetary Systems", which will cover protoplanetary disks, brown dwarfs, gas giant planets, terrestrial planets, planetesimals, extrasolar planets and the dynamical evolution of planetary systems. The school will consist of lectures by international experts on both observational and theoretical aspects.

The following are the lecturers and titles in this school:

A.P. Boss (Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, USA) *Formation of Disks, Binary Stars, and Gas Giant Planets*
T. Guillot (Observatoire de la Cote d'Azur, France) *Formation of giant planets: constraints from interior models*
G. Laughlin (UCO/Lick Observatory, Univ. of California at Santa Cruz, USA) *Dynamical Interactions Among Extrasolar Planets*
S.J. Weidenschilling (Planetary Science Institute, USA) (To be announced)
S.V.W. Beckwith (Space Telescope Science Institute, USA) *Observing Protoplanetary Disks at Long Wavelengths*
D.A. Fischer (Dept. of Physics & Astronomy, San Francisco State Univ., USA) (To be announced)
P.W. Lucas (Centre for Astrophysics Research, Univ. of Hertfordshire, UK) *Polarimetry of Extrasolar Planets*
M.R. Meyer (Steward Observatory, University of Arizona, USA) *The Formation and Evolution of Planetary Systems: Placing Our Solar System in Context with the Spitzer Space Telescope*
B. Oppenheimer (Dept. of Astrophysics, American Museum of Natural History, USA) *Comparative Exoplanetary Science: A Technical Challenge Now, A Galaxy of Worlds Later*

For further information, please refer to the web site
http://www.kobe-u.ac.jp/21COEPS/SCHOOL/2005/2005_ischool.html

Deadline for Application is April 15, 2005.