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Abstracts of recently accepted papers

The low–mass Initial Mass Function in the Orion Nebula cluster based on HST/NICMOS III imaging

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We present deep HST/NICMOS Camera 3 F110W and F160W imaging of a 26'×33', corresponding to 3.1pc×3.8pc, non-contiguous field towards the Orion Nebula Cluster (ONC). The main aim is to determine the ratio of low–mass stars to brown dwarfs for the cluster as a function of radius out to a radial distance of 1.5pc. The sensitivity of the data outside the nebulous central region is F160W≤ 21.0 mag, significantly deeper than previous studies of the region over a comparable area. We create an extinction limited sample and determine the ratio of low–mass stars (0.08–1 $M_\odot$) to brown dwarfs (0.02–0.08$M_\odot$ and 0.03–0.08$M_\odot$) for the cluster as a whole and for several annuli. The ratio found for the cluster within a radius of 1.5pc is $R_{02} = N(0.08 - 1M_\odot)/N(0.02 - 0.08M_\odot) = 1.7 \pm 0.2$, and $R_{03} = N(0.08 - 1M_\odot)/N(0.03 - 0.08M_\odot) = 2.4 \pm 0.2$, after correcting for field stars. The ratio for the central 0.3pc×0.3pc region down to 0.03$M_\odot$ was previously found to be $R_{03} = 3.3^{+0.8}_{-0.7}$, suggesting the low–mass content of the cluster is mass segregated. We discuss the implications of a gradient in the ratio of stars to brown dwarfs in the ONC in the context of previous measurements of the cluster and for other nearby star forming regions. We further discuss the current evidence for variations in the low–mass IMF and primordial mass segregation.

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http://arxiv.org/abs/1108.5581

POISSON project - I - Emission lines as accretion tracers in young stellar objects: results from observations of Chamaeleon I and II sources

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We present the results of the analysis of low-resolution optical-near IR spectroscopy (0.6-2.4 μm) of a sample (47 sources) of Class I and Class II young stellar objects in the Chamaeleon I and II star-forming clouds. These data are part of the POISSON project (Protostellar Optical-Infrared Spectral Survey on NTT). The aim of the observations is to determine the accretion luminosity ($L_{\rm acc}$) and mass accretion rate ($\dot{M}_{acc}$) of the sources through the analysis of the detected emission features. Taking advantage of the wide wavelength range covered by our spectra, we also aim at verifying the reliability and consistency of the existing empirical relationships connecting emission line luminosity and $L_{\rm acc}$. We employ five different tracers ([Oi] λ6300, Hα, Caii λ8542, Paβ, and Brγ) to derive the accretion luminosity, and critically discuss the various determinations in the light of the source properties. The tracers provide $L_{\rm acc}$ values characterised by different scatters when plotted as a function of L_*. The Brγ relation appears to be the most reliable, because it gives the minimum dispersion of $L_{\rm acc}$ over the entire range of L_*, whereas the other tracers, in particular Hα, provide much more scattered $L_{\rm acc}$ results, which are not expected for the homogeneous sample of targets we are observing. The direct comparison between $L_{\rm acc}$(Brγ) and the accretion luminosity obtained from the other four tracers also shows systematic differences in the results provided by the empirical relationships. These may probably be ascribed to different excitation mechanisms that contribute to the line emission, which may vary between our sample and those where the relationships have been calibrated, which were mostly based on observations in Taurus. Adopting the accretion luminosities estimates derived from the Brγ line, we infer $L_{\rm acc}$ in the range 0.1 L_*–1 L_* for all sources, and $\dot{M}_{acc}$ of the order $10^{-7} - 10^{-9}$ M$_\odot$ yr^{-1}, in the range of values commonly obtained for Class II objects. The mass accretion rates derived in Cha I are roughly proportional to $M_*{}^2$, in agreement with the results found in other low-mass star-forming regions. We find that the discrepancies observed in the case of $L_{\rm acc}$(Brγ) and $L_{\rm acc}$(Paβ) can be related to different intrinsic Paβ/Brγ ratios. The derived ratios point to the existence of two different emission modalities, one that agrees with predictions of both wind and accretion models, the other suggesting optically thick emission from relatively small regions (10^{21}-10^{22} cm^{-3}) with gas at low temperatures (<4000 K), the origin of which needs additional investigation.

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A Bubbling Nearby Molecular Cloud: COMPLETE Shells in Perseus

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We present a study on the shells (and bubbles) in the Perseus molecular cloud using the COMPLETE survey large-scale ^{12}CO(1-0) and ^{13}CO(1-0) maps. The twelve shells reported here are spread throughout most of the Perseus cloud and have circular or arc-like morphologies with a range in radius of about 0.1 to 3 pc. Most of them have not been detected before most likely as maps of the region lacked the coverage *and* resolution needed to distinguish them. The majority of the shells are coincident with infrared nebulosity of similar shape and have a candidate powering source near the center. We suggest they are formed by the interaction of spherical or very wide-angle winds powered by young stars inside or near the Perseus molecular cloud —a cloud that is commonly considered to be mostly forming low-mass stars. Two of the twelve shells are powered by high-mass stars close to the cloud, while the others appear to be powered by low or intermediate mass stars in the cloud. We argue that winds with a mass loss rate of about 10^{-8} to 10^{-6} M$_\odot$ yr^{-1} are required to produce the observed shells. Our estimates indicate that the energy input rate from these stellar winds is similar to the turbulence dissipation rate. We conclude that in Perseus the total energy input from both collimated protostellar outflows and powerful spherical winds from young stars is sufficient to maintain the turbulence in the molecular cloud. Large scale molecular line and IR continuum maps of a sample of clouds will help determine the frequency of this phenomenon in other star forming regions.

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High Cadence Time-Series Photometry of V1647 Orionis

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We present high cadence (1–10 hr^{-1}) time-series photometry of the eruptive young variable star V1647 Orionis during its 2003–2004 and 2008–2009 outbursts. The 2003 light curve was obtained mid-outburst at the phase of steepest luminosity increase of the system, during which time the accretion rate of the system was presumably continuing to increase toward its maximum rate. The 2009 light curve was obtained after the system luminosity had plateaued, presumably when the rate of accretion had also plateaued. We detect a 'flicker noise' signature in the power spectrum of the lightcurves, which may suggest that the stellar magnetosphere continued to interact with the accretion disk during each outburst event. Only the 2003 power spectrum, however, evinces a significant signal with a period of 0.13 d. While the 0.13 d period cannot be attributed to the stellar rotation period, we show that it may plausibly be due to short-lived radial oscillations of the star, possibly caused by the surge in the accretion rate.

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Collapse of a molecular cloud core to stellar densities: the formation and evolution of pre-stellar discs

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We report results from radiation hydrodynamical simulations of the collapse of molecular cloud cores to form protostars. The calculations follow the formation and evolution of the first hydrostatic core/disc, the collapse to form a stellar core, and effect of stellar core formation on the surrounding disc and envelope. Past barotropic calculations have shown that rapidly-rotating first cores evolve into 'pre-stellar discs' with radii up to $\sim$ 100 AU that may last thousands of years before a stellar core forms. We investigate how the inclusion of a realistic equation of state and radiative transfer alters this behaviour, finding that the qualitative behaviour is similar, but that the pre-stellar discs may last $1.5 - 3$ times longer in the more realistic calculations. The masses, radii, and lifetimes of the discs increase for initial molecular cloud cores with faster rotation rates. In the most extreme case we model, a pre-stellar disc with a mass of 0.22 Msun and a radius of $\approx$ 100 AU can form in a solar-mass cloud and last several thousand years before a stellar core is formed. Such large, massive objects may be imaged using ALMA. Fragmentation of these massive discs may also provide an effective route to binary and multiple star formation, before radiative feedback from accretion onto the stellar core can inhibit fragmentation. Once collapse to form a stellar core occurs within the pre-stellar disc, the radiation hydrodynamical simulations produce qualitatively different behaviour from the barotropic calculations due to the accretion energy released. This drives a shock wave through the circumstellar disc and launches a bipolar outflow even in the absence of magnetic fields.

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Animations available from http://www.astro.ex.ac.uk/people/mbate/

Multi-line spectral imaging of dense cores in the Lupus molecular cloud

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The molecular clouds Lupus 1, 3 and 4 were mapped with the Mopra telescope at 3 and 12 mm. Emission lines from high density molecular tracers were detected, i.e. NH_3 (1,1), NH_3 (2,2), N_2H^+ (1-0), HC_3N (3-2), HC_3N (10-9), CS (2-1), CH_3OH (2_0-1_0)A^+ and CH_3OH (2_{-1}-1_{-1})E. Velocity gradients of more than 1 km s^{-1} are present in Lupus 1 and 3 and multiple gas components are present in these clouds along some lines of sight. Lupus 1 is the cloud richest in high density cores, 8 cores were detected in it, 5 cores were detected in Lupus 3 and only 2 in Lupus 4. The intensity of the three species HC_3N NH_3 and N_2H^+ changes significantly in the various cores: cores that are brighter in HC_3N are fainter or undetected in NH_3 and N_2H^+ and vice versa. We found that the column density ratios HC_3N/N_2H^+ and HC_3N/NH_3 change by one order of magnitude between the cores, indicating that also the chemical abundance of these species is different. The time dependent chemical code that we used to model our cores shows that the HC_3N/N_2H^+ and HC_3N/NH_3 ratios decrease with time therefore the observed column density of these species can be used as an indicator of the chemical evolution of dense cores. On this base we classified 5 out of 8 cores in Lupus 1 and 1 out of 5 cores in Lupus 3 as very young protostars or prestellar cores. Comparing the millimetre cores population with the population of the more evolved young stellar objects identified in the Spitzer surveys, we conclude that in Lupus 3 the bulk of the star formation activity has already passed and only a moderate number of stars are still forming. On the contrary, in Lupus 1 star formation is on-going and several dense cores are still in the pre–/proto–stellar phase. Lupus 4 is at an intermediate stage, with a smaller number of individual objects.

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Age spread in W3 Main: LBT/LUCI near-infrared spectroscopy of the massive stellar content

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We present near-infrared multi-object spectroscopy and JHK_s imaging of the massive stellar content of the Galactic star-forming region W3 Main, obtained with LUCI at the Large Binocular Telescope. We confirm 15 OB stars in W3 Main and derive spectral types between O5V and B4V from their absorption line spectra. Three massive Young Stellar Objects are identified by their emission line spectra and near-infrared excess. The color-color diagram of the detected sources allows a detailed investigation of the slope of the near-infrared extinction law towards W3 Main. Analysis of the Hertzsprung Russell diagram suggests that the Nishiyama extinction law fits the stellar population of W3 Main best ($E(J-H)/E(H-K_s) = 1.76$ and $R_{K_s} = 1.44$). From our spectrophotometric analysis of the massive stars and the nature of their surrounding HII regions we derive the evolutionary sequence of W3 Main and we find evidence of an age spread of at least 2-3 Myr. While the most massive star (IRS2) is already evolved, indications for high-mass pre–main-sequence evolution is found for another star (IRS N1), deeply embedded in an ultra compact HII region, in line with the different evolutionary phases observed in the corresponding HII regions. We derive a stellar mass of W3 Main of $(4 \pm 1) \times 10^3 M_\odot$, by extrapolating from the number of OB stars using a Kroupa IMF and correcting for our spectroscopic incompleteness. We have detected the photospheres of OB stars from the more evolved diffuse HII region to the much younger UCHII regions, suggesting that these stars have finished their formation and cleared away their circumstellar disks very fast. Only in the hyper-compact HII region (IRS5), the early type stars seem to be still surrounded by circumstellar material.

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http://www.mpia-hd.mpg.de/homes/abik

Supernova enhanced cosmic-ray ionization and induced chemistry in a molecular cloud of W51C

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Cosmic rays pervade the Galaxy and are thought to be accelerated in supernova shocks. The interaction of cosmic rays with dense interstellar matter has two important effects: 1) high energy ($>$ 1 GeV) protons produce γ-rays by π^0-meson decay; 2) low energy ($<$ 1 GeV) cosmic rays (protons and electrons) ionize the gas. We present here new observations towards a molecular cloud close to the W51C supernova remnant and associated with a recently discovered TeV γ-ray source. Our observations show that the cloud ionization degree is highly enhanced, implying a cosmic ray ionization rate $\sim 10^{-15}$ s^{-1}, i.e. 100 times larger than the standard value in molecular clouds. This is consistent with the idea that the cloud is irradiated by an enhanced flux of freshly accelerated low-energy cosmic rays. In addition, the observed high cosmic ray ionization rate leads to an instability in the chemistry of the cloud, which keeps the electron fraction high, $\sim 10^{-5}$, in a large fraction ($A_V \geq 6$ mag) of the cloud and low, $\sim 10^{-7}$, in the interior. The two states have been predicted in the literature as high- and low-ionization phases (HIP and LIP). This is the first observational evidence of their simultaneous presence in a cloud.

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Dimensional argument for the impact of turbulent support on the stellar initial mass function

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We present a simple dimensional argument to illustrate the impact of nonthermal support from turbulent velocity dispersion on the shape of the prestellar core mass function (CMF), precursor of the stellar initial mass function (IMF). The argument demonstrates the need to invoke such support to recover the Salpeter slope in the high-mass part of the CMF/IMF, whereas pure thermal support leads to a much steeper slope. This simple dimensional argument clearly highlights the results obtained in the complete Hennebelle-Chabrier theory of the IMF.

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A deep search for H2D$^+$ in protoplanetary disks. Perspectives for ALMA

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Context. The structure in density and temperature of protoplanetary disks surrounding low-mass stars is not well known yet. The protoplanetary disks' midplane are expected to be very cold and thus depleted in molecules in gas phase, especially CO. Recent observations of molecules at very low apparent temperatures ($\sim$ 6 K) challenge this

current picture of the protoplanetary disk structures.
Aims. We aim at constraining the physical conditions and, in particular, the gas-phase CO abundance in the midplane of protoplanetary disks.
Methods. The light molecule H_2D^+ is a tracer of cold and CO-depleted environment. It is therefore a good candidate for exploring the disks midplanes. We performed a deep search for H_2D^+ in the two well-known disks surrounding TW Hya and DM Tau using the APEX and JCMT telescopes. The analysis of the observations was done with DISKFIT, a radiative transfer code dedicated to disks. In addition, we used a chemical model describing deuterium chemistry to infer the implications of our observations on the level of CO depletion and on the ionization rate in the disk midplane.
Results. The ortho-H_2D^+ ($1_{1,0} - 1_{1,1}$) line at 372 GHz was not detected. Although our limit is three times better than previous observations, comparison with the chemical modeling indicates that it is still insufficient for putting useful constraints on the CO abundance in the disk midplane.
Conclusions. Even with ALMA, the detection of H_2D^+ may not be straightforward, and H_2D^+ may not be sensitive enough to trace the protoplanetary disks midplane.

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Deep Very Large Array Radio Continuum Surveys of GLIMPSE Extended Green Objects (EGOs)

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We present the results of deep, high angular resolution Very Large Array (VLA) surveys for radio continuum emission towards a sample of 14 GLIMPSE Extended Green Objects (EGOs). Identified as massive young stellar object (MYSO) outflow candidates based on their extended 4.5 μm emission in *Spitzer* images, the EGOs in our survey sample are also associated with 6.7 GHz Class II and/or 44 GHz Class I CH_3OH masers. No continuum is detected at 3.6 or 1.3 cm towards the majority (57%) of our targets (median rms ∼0.03 and 0.25 mJy beam^{-1}). Only two EGOs are associated with optically thin emission consistent with ultracompact/compact HII regions. Both of these sources exhibit cm$-\lambda$ multiplicity, with evidence that one of the less-evolved members may be driving the 4.5 μm outflow. Most of the other cm-λ EGO counterparts are weak ($\lesssim$1 mJy), unresolved, undetected at 1.3 cm, and characterized by intermediate spectral indices consistent with hypercompact (HC) HII regions or ionized winds or jets. One EGO cm counterpart, likely an optically thick HC HII region, is detected only at 1.3 cm and is associated with hot core line emission and H_2O and 6.7 GHz CH_3OH masers. The results of our exceptionally sensitive survey indicate that EGOs signify an early stage of massive star formation, before photoionizing feedback from the central MYSO significantly influences the (proto)cluster environment. Actively driving outflows (and so, presumably, actively accreting), the surveyed EGOs are associated with significant clump-scale gas reservoirs, providing sufficient material for sustained, rapid accretion.

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Ionized Gas Kinematics and Morphology in Sgr B2 Main on 1000 AU Scales

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We have imaged the Sgr B2 Main region with the Very Large Array in the BnA configuration ($\theta_{beam} = 0.13$ arcsec) in both the H52α (45.453 GHz) radio recombination line (RRL) and 7 mm continuum emission. At a distance of 8500 pc, this spatial resolution corresponds to a physical scale of 0.005 pc (∼1100 AU). The current observations detect H52α

emission in 12 individual ultracompact (UC) and hypercompact (HC) HII regions. Two of the sources with detected H52 α emission have broad ($\Delta V_{FWHM} \sim$50 km s^{-1}) recombination lines, and two of the sources show lines with peaks at more than one velocity. We use line parameters from the H52α lines and our previous H66α line observations to determine the relative contribution of thermal, pressure and kinematic broadening, and electron density. These new observations suggest that pressure broadening can account for the broad lines in some of the sources, but that gas motions (e.g. turbulence, accretion or outflow) contribute significantly to the broad lines in at least one of the sources (Sgr B2 F3).

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Starless Cloud Core L1517B in Envelope Expansion with Core Collapse

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Various spectral emission lines from star-forming molecular cloud core L1517B manifest red asymmetric double-peaked profiles with stronger red peaks and weaker blue peaks, in contrast to the oft- observed blue-skewed molecular spectral line profiles with blue peaks stronger than red peaks. Invoking a spherically symmetric general polytropic hydrodynamic shock model for the envelope expansion with core collapse (EECC) phase, we show the radial flow velocity, mass density and temperature structures of self-similar evolution for L1517B in a dynamically consistent manner. By prescribing simple radial profiles of abundance distribution for pertinent molecules, we perform molecular excitation and radiative transfer calculations using the publicly available RATRAN code set for the spherically symmetric case. Emphatically, spectral profiles of line emissions from the same molecules but for different line transitions as well as spectra of closely pertinent isotopologues strongly constrain the self-similar hydrodynamics of a cloud core with prescribed abundances. Our computational results show that the EECC model reproduces molecular spectral line profiles in sensible agreement with observational data of Institut de Radioastronomie Millimetrique (IRAM), Five College Radio Astronomical Observatory (FCRAO) and Effelsberg 100 m telescopes for L1517B. We also report spatially resolved observations of optically thick line HCO+(1-0) using the Purple Mountain Observatory (PMO) 13.7 m telescope at Delingha in China and the relevant fitting results. Hyperfine line structures of NH3 and N2H+ transitions are also fitted to consistently reveal the dynamics of central core collapse. As a consistent model check, radial profiles of 1.2 mm and 850 μm dust continua observed by IRAM 30 m telescope and the Submillimeter Common-User Bolometer Array (SCUBA), respectively, are also fitted numerically using the same EECC model that produces the molecular line profiles. L1517B is likely undergoing an EECC shock phase. For future observational tests, we also predict several molecular line profiles with spatial distributions, radial profile of sub-millimeter continuum at wavelength 450 μm, as well as the radial profiles of the column density and visual extinction for L1517B.

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The nature of the embedded intermediate-mass T Tauri star DK Cha

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Most of our knowledge about star formation is based on studies of low-mass stars, whereas very little is known about the properties of the circumstellar material around young and embedded intermediate-mass T Tauri stars (IMTTSs) mostly because they are rare, typically more distant than their lower mass counterparts, and their nearby circumstellar surroundings are usually hidden from us. We present an analysis of the excitation and accretion properties of the young IMTTS DK Cha. The nearly face-on configuration of this source allows us to have direct access to the star-disk system through the excavated envelope and outflow cavity. Based on low-resolution optical and infrared spectroscopy obtained with SofI and EFOSC2 on the NTT we derive the spectrum of DK Cha from $\sim$0.6 μm to $\sim$2.5 μm. From the detected lines we probe the conditions of the gas that emits the HI IR emission lines and obtain insights into the origin of the other permitted emission lines. In addition, we derive the mass accretion rate ($\dot{M}_{acc}$) from the relationships that connect the luminosity of the Brγ and Paβ lines with the accretion luminosity ($L_{\rm acc}$). The observed optical/IR spectrum is extremely rich in forbidden and permitted atomic and molecular emission lines, which makes this source similar to very active low-mass T Tauri stars. Some of the permitted emission lines are identified as being excited by fluorescence. We derive Brackett decrements and compare them with different excitation mechanisms. The Paβ/Brγ ratio is consistent with optically thick emission in LTE at a temperature of $\sim$ 3500 K, originated from a compact region of $\sim$ 5 $R_\odot$ in size: but the line opacity decreases in the Br lines for high quantum numbers n_{up}. A good fit to the data is obtained assuming an expanding gas in LTE, with an electron density at the wind base of $\sim 10^{13}\,{\rm cm}^{-3}$. In addition, we find that the observed Brackett ratios are very similar to those reported in previous studies of low-mass CTTSs and Class I sources, indicating that these ratios are not dependent on masses and ages. Finally, $L_{acc} \sim 9\,L_\odot$ and $\dot{M}_{acc} \sim 3\times10^{-7}\,M_\odot\,{\rm yr}^{-1}$ values were found. When comparing the derived $\dot{M}_{acc}$ value with that found in Class I and IMTTSs of roughly the same mass, we found that $\dot{M}_{acc}$ in DK Cha is lower than that found in Class I sources but higher than that found in IMTTSs. This agrees with DK Cha being in an evolutionary transition phase between a Class I and II source.

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Dense core formation by fragmentation of velocity-coherent filaments in L1517

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Context: Low-mass star-forming cores differ from their surrounding molecular cloud in turbulence, shape, and density structure.
Aims: We aim to understand how dense cores form out of the less dense cloud material by studying the connection between these two regimes.
Methods: We observed the L1517 dark cloud in $C^{18}O(1\text{–}0)$, $N_2H^+(J{=}1\text{–}0)$, and $SO(J_N{=}3_2\text{–}2_1)$ with the FCRAO 14m telescope, and in the 1.2mm dust continuum with the IRAM 30m telescope.
Results: Most of the gas in the cloud lies in four filaments that have typical lengths of 0.5 pc. Five starless cores are embedded in these filaments and have chemical compositions indicative of different evolutionary stages. The filaments have radial profiles of $C^{18}O(1\text{–}0)$ emission with a central flattened region and a power-law tail, and can be fitted approximately as isothermal, pressure-supported cylinders. The filaments, in addition, are extremely quiescent. They have subsonic internal motions and are coherent in velocity over their whole length. The large-scale motions in the filaments can be used to predict the velocity inside the cores, indicating that core formation has not decoupled the dense gas kinematically from its parental material. In two filaments, these large-scale motions consist of oscillations in the velocity centroid, and a simple kinematic model suggests that they may be related to core-forming flows.
Conclusions: Core formation in L1517 seems to have occurred in two steps. First, the subsonic, velocity-coherent filaments have condensed out of the more turbulent ambient cloud. Then, the cores fragmented quasi-statically and inherited the kinematics of the filaments. Turbulence dissipation has therefore occurred mostly on scales on the order of 0.5 pc or larger, and seems to have played a small role in the formation of the individual cores.

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The Relationship between Accretion Disc Age and Stellar Age and its Consequences for Proto-Stellar Discs

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We show that for young stars which are still accreting and for which measurements of stellar age, disc mass and accretion rate are available, nominal disc age (Disc Age = Disc Mass / Accretion Rate) is approximately equal to the stellar age, at least within the considerable observational scatter. We then consider theoretical models of proto-stellar discs through analytic and numerical models. A variety of viscosity prescriptions including empirical power laws, magnetohydrodynamic turbulence and gravitational instability were considered within models describing the disc phenomena of dead zones, photoevaporation and planet formation. These models are generally poor fits to the observational data, showing values of 'Disc Age' which are too high by factors of 3 - 10. We then ask whether a systematic error in the measurement of one of the observational quantities might provide a reasonable explanation for this discrepancy. We show that for the observed systems only disc mass shows a systematic dependence on the value of 'Disc Age / Stellar Age' and we note that a systematic underestimate of the value of disc mass by a factor of around 3 - 5, would account for the discrepancy between theory and observations.

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Arcsecond resolution images of the chemical structure of the low-mass protostar IRAS 16293-2422 – An overview of a large molecular line survey from the Submillimeter Array

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It remains a key challenge to establish the molecular content of different components of low-mass protostars, like their envelopes and disks, and how this depends on the evolutionary stage and/or environment of the young stars. Observations at submillimeter wavelengths provide a direct possibility to study the chemical composition of low-mass protostars through transitions probing temperatures up to a few hundred K in the gas surrounding these sources. This paper presents a large molecular line survey of the deeply embedded protostellar binary IRAS 16293-2422 from the Submillimeter Array (SMA) – including images of individual lines down to ≈ 1.5–3 arcsec (190–380 AU) resolution. More than 500 individual transitions are identified related to 54 molecular species (including isotopologues) probing temperatures up to about 550 K. Strong chemical differences are found between the two components in the protostellar system with a separation between, in particular, the sulfur- and nitrogen-bearing species and oxygen-bearing complex organics. The action of protostellar outflow on the ambient envelope material is seen in images of CO and SiO and appear to influence a number of other species, including (deuterated) water, HDO. The effects of cold gas-phase chemistry is directly imaged through maps of CO, N_2D^+ and DCO^+, showing enhancements of first DCO^+ and subsequently N_2D^+ in the outer envelope where CO freezes-out on dust grains.

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Sub-Alfvenic Non-Ideal MHD Turbulence Simulations with Ambipolar Diffusion: III. Implications for Observations and Turbulent Enhancement

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Ambipolar diffusion (AD) is believed to be a crucial process for redistributing magnetic flux in the dense molecular gas that occurs in regions of star formation. We carry out numerical simulations of this process in regions of low ionization using the heavy ion approximation. The simulations are for regions of strong field (plasma beta=0.1) and mildly supersonic turbulence (M=3, corresponding to an Alfven mach number of 0.67). The velocity power spectrum of the neutral gas changes from an Iroshnikov-Kraichnan spectrum in the case of ideal MHD to a Burgers spectrum in the case of a shock-dominated hydrodynamic system. The magnetic power spectrum shows a similar behavior. We use a 1D radiative transfer code to post-process our simulation results; the simulated emission from the CS J=2-1 and H13CO+ J=1-0 lines shows that the effects of AD are observable in principle. Linewidths of ions are observed to be less than those of neutrals, and we confirm previous suggestions that this is due to AD. We show that AD is unlikely to affect the Chandrasekhar-Fermi method for inferring field strengths unless the AD is stronger than generally observed. Finally, we present the first fully 3D study of the enhancement of AD by turbulence, finding that AD is accelerated by factor 2-4.5 for non self-gravitating systems with the level of turbulence we consider.

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The Gravo-Magneto Limit Cycle in Accretion Disks

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Previous theoretical studies have found that repeating outbursts can occur in certain regions of an accretion disk, due to sudden transitions in time from gravitationally produced turbulence to magnetically produced turbulence. We analyze the disk evolution in a state diagram that plots the mass accretion rate versus disk surface density. We determine steady state accretion branches that involve gravitational and magnetic sources of turbulence. Using time-dependent numerical disk simulations, we show that cases having outbursts track along a nonsteady 'dead zone' branch and some steady state accretion branches. The outburst is the result of a rapid inter-branch transition. The gravo-magneto outbursts are then explained on this diagram as a limit cycle that is analogous to the well-known S-curve that has been applied to dwarf nova outbursts. The diagram and limit cycle provide a conceptual framework for understanding the nature of the outbursts that may occur in accretion disks of all scales, from circumplanetary to protoplanetary to AGN accretion disks.

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Circumbinary disc survival during binary-single scattering: towards a dynamical model of the Orion BN/KL complex

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The Orion BN/KL complex is the nearest site of ongoing high-mass star formation. Recent proper motion observations provide convincing evidence of a recent (about 500 years ago) dynamical interaction between two massive young stellar objects in the region resulting in high velocities: the BN object and radio Source I. At the same time, Source I is surrounded by a nearly edge-on disc with radius 50 au. These two observations taken together are puzzling: a dynamical encounter between multiple stars naturally yields the proper motions, but the survival of a disc is challenging to explain. In this paper we take the first steps to numerically explore the preferred dynamical scenario of Goddi et al., in which Source I is a binary that underwent a scattering encounter with BN, in order to determine if a pre-existing disc can survive this encounter in some form. Treating only gravitational forces, we are able to thoroughly and efficiently cover a large range of encounter parameters. We find that disc material can indeed survive a three-body scattering event if 1) the encounter is close, i.e. BN's closest approach to Source I is comparable to Source I's semi-major axis; and 2) the interplay of the three stars is of a short duration. Furthermore, we are able to constrain the initial conditions that can broadly produce the orientation of the present-day system's disc relative to its velocity vector. To first order we can thus confirm the plausibility of the scattering scenario of Goddi et al., and we have significantly constrained the parameters and narrowed the focus of future, more complex and expensive attempts to computationally model the complicated BN/KL region.

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Hydrodynamic outcomes of planet scattering in transitional discs

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A significant fraction of unstable multiple planet systems likely scatter during the transitional disc phase as gas damping becomes ineffectual. Using an ensemble of FARGO hydrodynamic simulations and MERCURY n-body integrations, we directly follow planet-disc and planet-planet interactions through the clearing phase and on through 50 Myr of dynamical evolution. Disc clearing occurs via X-ray driven photoevaporation. The hydrodynamic evolution of individual scattering systems is complex, and involves phases in which massive planets orbit within eccentric gaps, or accrete directly from the disc without a gap. Comparing the results to a gas-free model, we find that the n-body dynamics and hydrodynamics of scattering into one- and two-planet final states are almost identical. The eccentricity distributions in these channels are almost unaltered by the presence of gas. The hydrodynamic simulations, however, also form low eccentricity three-planet systems in long-term stable configurations, and the admixture of these systems results in modestly lower eccentricities in hydrodynamic as opposed to gas-free simulations. The incidence of these three-planet systems is likely a function of the initial conditions; different planet setups (number or spacing) may change the character of this result. We analyze the properties of surviving multiple planet systems, and show that only a small fraction (a few percent) enter mean-motion resonances after scattering, while a larger fraction form stable resonant chains and avoid scattering entirely. Our results remain consistent with the hypothesis that exoplanet eccentricity results from scattering, though the detailed agreement between observations and gas-free simulation results is likely coincidental. We discuss the prospects for testing scattering models by observing planets or non-axisymmetric gas structure in transitional discs.

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Spectroscopic properties of Young Stellar Objects in the Lupus Molecular Clouds

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The results of an optical spectroscopic survey of a sample of young stellar objects (YSOs) and pre-main sequence (PMS) stars in the Lupus Clouds are presented. 92 objects were observed with VLT/FLAMES. All of those objects show IR excess as discovered by the *Spitzer* Legacy Program "From Molecular Cores to Planet-Forming Disks" (c2d). After

reduction, 54 spectra with good signal-to-noise ratio are spectrally classified. Effective temperatures and luminosities are derived for these objects, and used to construct H-R diagrams for the population. The sample consists mostly of M-type stars, with 10% K-type stars. Individual ages and masses are inferred for the objects according to theoretical evolutionary models. The mean population age is found to be between 3.6 and 4.4 Myr, depending on the model, while the mean mass is found to be $\sim 0.3\ M_\odot$ for either model. Together with literature data, the distribution of spectral types is found to be similar to that in Chamaeleon I and IC348. The Hα line in emission, found in 49% of the sample, is used to distinguish between classical and weak-line T Tauri stars. 56% of the objects show Hα in emission and are accreting T Tauri stars. Mass accretion rates between 10^{-8} and 10^{-11} $M_\odot yr^{-1}$ are determined from the full width at 10% of the Hα peak intensity. These mass accretion rates are, within a large scatter, consistent with the $\dot{M}_{ac} \propto M^2$ relation found in the literature.

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The Herschel view of massive star formation in G035.39–00.33: a dense and cold filament of W48 undergoing a mini-starburst

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The filament IRDC G035.39–00.33 in the W48 molecular complex is one of the darkest infrared clouds observed by *Spitzer*. It has been observed by the PACS (70 and 160 μm) and SPIRE (250, 350 and 500 μm) cameras of the *Herschel* Space Observatory as part of the W48 molecular cloud complex in the framework of the HOBYS key programme. The observations reveal a sample of 28 compact sources (deconvolved FWHM sizes <0.3 pc) complete down to $\sim 5\ M_\odot$ in G035.39–00.33 and its surroundings. Among them, 13 compact sources are massive dense cores with masses $>20\ M_\odot$. The cloud characteristics we derive from the analysis of their spectral energy distributions (20-50 $M_\odot$ with sizes of 0.1–0.2 pc and average densities of 2-20 $\times$ 10^5 cm^{-3}) make these massive dense cores excellent candidates to form intermediate- to high-mass stars. Most of the massive dense cores are located inside the G035.39–00.33 filament and host IR-quiet high-mass protostars. The large number of protostars found in this filament suggests that we are witnessing a mini-burst of star formation with an efficiency of $\sim$20% and a rate density of $\sim 40\ M_\odot yr^{-1}\ kpc^{-2}$ within a ~ 8 pc^2 area. Part of the extended SiO emission observed toward G035.39–00.33 is not associated with obvious protostars and may originate from low-velocity shocks within converging flows, as advocated by previous studies.

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Hydrogen cyanide and isocyanide in prestellar cores

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Aims: We studied the abundance of HCN, $H^{13}CN$, and $HN^{13}C$ in a sample of prestellar cores, in order to search for species associated with high density gas.
Methods: We used the IRAM 30m radiotelescope to observe along the major and the minor axes of L1498, L1521E,

and TMC 2, three cores chosen on the basis of their CO depletion properties. We mapped the $J = 1 \rightarrow 0$ transition of HCN, $H^{13}CN$, and $HN^{13}C$ towards the source sample plus the $J = 1 \rightarrow 0$ transition of N_2H^+ and the $J = 2 \rightarrow 1$ transition of $C^{18}O$ in TMC 2. We used two different radiative transfer codes, making use of recent collisional rate calculations, in order to determine more accurately the excitation temperature, leading to a more exact evaluation of the column densities and abundances.
Results: We find that the optical depths of both $H^{13}CN(1-0)$ and $HN^{13}C(1-0)$ are non-negligible, allowing us to estimate excitation temperatures for these transitions in many positions in the three sources. The observed excitation temperatures are consistent with recent computations of the collisional rates for these species and they correlate with hydrogen column density inferred from dust emission. We conclude that HCN and HNC are relatively abundant in the high density zone, $n(H_2) \sim 10^5$ cm^{-3}, where CO is depleted. The relative abundance [HNC]/[HCN] differs from unity by at most 30% consistent with chemical expectations. The three hyperfine satellites of HCN(1−0) are optically thick in the regions mapped, but the profiles become increasingly skewed to the blue (L1498 and TMC 2) or red (L1521E) with increasing optical depth suggesting absorption by foreground layers.

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The enigmatic core L1451-mm: a first hydrostatic core? or a hidden VeLLO?

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We present the detection of a dust continuum source at 3-mm (CARMA) and 1.3-mm (SMA), and ^{12}CO (2–1) emission (SMA) towards the L1451-mmdense core. These detections suggest a compact object and an outflow where no point source at mid-infrared wavelengths is detected using Spitzer. An upper limit for the dense core bolometric luminosity of $0.05\,L_\odot$is obtained.
By modeling the broadband SED and the continuum interferometric visibilities simultaneously, we confirm that a central source of heating is needed to explain the observations.
This modeling also shows that the data can be well fitted by a dense core with a YSO and disk, or by a dense core with a central First Hydrostatic Core (FHSC). Unfortunately, we are not able to decide between these two models, which produce similar fits. We also detect ^{12}CO (2–1) emission with red- and blue-shifted emission suggesting the presence of a slow and poorly collimated outflow, in opposition to what is usually found towards young stellar objects but in agreement with prediction from simulations of a FHSC.
This presents the best candidate, so far, for a FHSC, an object that has been identified in simulations of collapsing dense cores.
Whatever the true nature of the central object in L1451-mm, this core presents an excellent laboratory to study the earliest phases of low-mass star formation.

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Multi-scale Analysis of Magnetic Fields in Filamentary Molecular Clouds in Orion A

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New visible and K-band polarization measurements on stars surrounding molecular clouds in Orion A and stars in the BN vicinity are presented. Our results confirm that magnetic fields located inside the Orion A molecular clouds and in their close neighborhood are spatially connected. On and around the BN object, we measured the angular offsets between the K-band polarization data and available submm data. We find high values of the polarization degree, P_K, and of the optical depth, τ_K, close to an angular offset position of 90° whereas lower values of P_K and τ_K are observed for smaller angular offsets. We interpret these results as evidence for the presence of various magnetic field components toward lines of sight in the vicinity of BN. On a larger scale, we measured the distribution of angular offsets between available H-band polarization data and the same submm data set. Here we find an increase of $< P_H >$ with angular offset which we interpret as a rotation of the magnetic field by $\lesssim$60°. This trend generalizes previous results on small scale toward and around lines of sight to BN and is consistent with a twist of the magnetic field on a larger scale towards OMC-1. A comparison of our results with several other studies suggests that a two-component magnetic field, maybe helical, could be wrapping the OMC-1 filament.

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Hot Molecular Cores in Infrared Dark Clouds

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We present high-angular resolution continuum images and molecular line spectra obtained at 345 GHz with the Submillimeter Array toward two massive cores that lie within Infrared Dark Clouds (IRDCs), G034.43+00.24 MM1 and G024.33+00.11 MM1. Both of these cores contain bright, unresolved (< 2") objects that have previously been imaged in the mm/sub-mm continuum with the IRAM PdBI and SMA and show complex molecular line chemistry. The new, higher angular resolution SMA continuum images reveal that both cores contain massive (8, 26 $M_\odot$), unresolved (0.6 arcsec; $\sim$ 3000 AU) continuum emission features and emission from many complex molecular transitions, which confirm that these are Hot Molecular Cores (HMCs), an early stage in the formation of a high-mass star. Because these hot cores are located within IRDCs, they may well represent the very earliest phases in the formation of high-mass protostars and, hence, their detailed study may reveal the initial conditions within high-mass star-forming cores, before they are shredded apart by stellar winds and radiation.

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Quantitative evidence of an intrinsic luminosity spread in the Orion Nebula Cluster

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We study the distribution of stellar ages in the Orion Nebula Cluster (ONC) using accurate HST photometry taken from HST Treasury Program observations of the ONC utilizing the cluster distance estimated by Menten and collaborators. We investigate whether there is an intrinsic age spread in the region and whether the age depends on the spatial distribution. We estimate the extinction and accretion luminosity towards each source by performing synthetic photometry on an empirical calibration of atmospheric models using the package *Chorizos* of Maiz-Apellaniz. The position of the sources in the HR-diagram is compared with different theoretical isochrones to estimate the mean cluster age and age dispersion. On the basis of Monte Carlo simulations, we quantify the amount of intrinsic age spread in the region, taking into account uncertainties in the distance, spectral type, extinction, unresolved binaries, accretion, and photometric variability. According to the evolutionary models of Siess and collaborators, the mean age of the Cluster is 2.2 Myr with a scatter of few Myrs. With Monte Carlo simulations, we find that the observed age spread is inconsistent with that of a coeval stellar population, but in agreement with a star formation activity between 1.5 and 3.5 Myrs. We also observe some evidence that ages depends on the spatial distribution.

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The extinction map of the OMC-1 molecular cloud behind the Orion Nebula

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The Orion Nebula and its associated young stellar cluster are located at the front-side of the optically thick OMC-1 molecular cloud. In order to disentangle the cluster members from background contamination, it is important to know the extinction provided by the OMC-1, which is poorly known, the available measurements yielding contradictory results. Our main goal is to derive a new extinction map of the OMC-1, obtaining information about the structure of the OMC-1 and the Orion Nebula Cluster. The most recent near-infrared catalog of stars is used to study the distribution of reddening across a 0.3 deg^2 area covering the Orion Nebula Cluster. On the basis of the observed $(H, H-K_S)$ diagram, we establish a criterion for disentangling contaminants from bona-fide cluster members. For contaminant stars, interstellar reddenings are estimated by comparison with a synthetic galactic model. A statistical analysis is then performed to consistently account for local extinction, reddening and star-counts analysis. We derive the extinction map of the OMC-1 with angular resolution $<5'$. We also assemble a sample of candidate cluster members, for which we measure the extinction provided by the nebular environment. These extinction measurements are analyzed similarly to the contaminant sample, and an extinction map of the Orion Nebula is derived. The extinction provided by the OMC-1 is variable on spatial scales of a few arcminutes, while showing a general increase from the outskirts ($A_V \sim 6$) to the direction of the Trapezium asterism ($A_V > 30$). The Orion Nebula extinction map is more irregular and optically thinner, with A_V of the order of a few magnitudes. Both maps are consistent with the optical morphology, in particular the Dark Bay to the north-east of the Trapezium. Both maps also show the presence of a north-south high-density ridge, which confirms the filamentary structure of the Orion molecular complex inside which star formation is still taking place.

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Magnetic activity and accretion on FU Tau A: Clues from variability

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FU Tau A is a young very low mass object in the Taurus star forming region which was previously found to have strong X-ray emission and to be anomalously bright for its spectral type. In this study we discuss these characteristics using new information from quasi-simultaneous photometric and spectroscopic monitoring. From photometric time series obtained with the 2.2 m telescope on Calar Alto we measure a period of ~ 4 d for FU Tau A, most likely the rotation period. The short-term variations over a few days are consistent with the rotational modulation of the flux by cool, magnetically induced spots. In contrast, the photometric variability on timescales of weeks and years can only be explained by the presence of hot spots, presumably caused by accretion. The hot spot properties are thus variable on timescales exceeding the rotation period, maybe due to long-term changes in the accretion rate or geometry. The new constraints from the analysis of the variability confirm that FU Tau A is affected by magnetically induced spots and excess luminosity from accretion. However, accretion is not sufficient to explain its anomalous position in the HR diagram. In addition, suppressed convection due to magnetic activity and/or an early evolutionary stage need to be invoked to fully account for the observed properties. These factors cause considerable problems in estimating the mass of FU Tau A and other objects in this mass/age regime, to the extent that it appears questionable if it is feasible to derive the Initial Mass Function for young low-mass stars and brown dwarfs.

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Magnetic fields during the early stages of massive star formation - I. Accretion and disc evolution

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We present simulations of collapsing 100 $M_\odot$ mass cores in the context of massive star formation. The effect of variable initial rotational and magnetic energies on the formation of massive stars is studied in detail. We focus on accretion rates and on the question under which conditions massive Keplerian discs can form in the very early evolutionary stage of massive protostars. For this purpose, we perform 12 simulations with different initial conditions extending over a wide range in parameter space. The equations of magnetohydrodynamics (MHD) are solved under the assumption of ideal MHD. We find that the formation of Keplerian discs in the very early stages is suppressed for a mass-to-flux ratio normalised to the critical value μ below 10, in agreement with a series of low-mass star formation simulations. This is caused by very efficient magnetic braking resulting in a nearly instantaneous removal of angular momentum from the disc. For weak magnetic fields, corresponding to $\mu \geq 10$, large-scale, centrifugally supported discs build up with radii exceeding 100 AU. A stability analysis reveals that the discs are supported against gravitationally induced perturbations by the magnetic field and tend to form single stars rather than multiple objects. We find protostellar accretion rates of the order of a few 10^{-4} $M_\odot$ yr^{-1} which, considering the large range covered by the initial conditions, vary only by a factor of ~ 3 between the different simulations. We attribute this fact to two competing effects of magnetic fields. On the one hand, magnetic braking enhances accretion by removing angular momentum from the disc thus lowering the centrifugal support against gravity. On the other hand, the combined effect of magnetic pressure and magnetic tension counteracts gravity by exerting an outward directed force on the gas in the disc thus reducing the accretion onto the protostars.

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Chemical evolution of turbulent protoplanetary disks and the Solar nebula

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This is the second paper in a series where we study the influence of transport processes on the chemical evolution of protoplanetary disks. Our analysis is based on a 1+1D flared α-model of a ~ 5 Myr DM Tau-like system, coupled to a large gas-grain chemical network. To account for production of complex molecules, the chemical network is supplied with an extended set of surface reactions and photo-processes in ice mantles. Our chemo-dynamical disk model covers a wide range of radii, 10–800 AU (from a Jovian planet-forming zone to the outer disk edge). Turbulent transport of gases and ices is implicitly modeled in full 2D along with the time-dependent chemistry, using the mixing-length approximation. Two regimes are considered, with high and low efficiency of turbulent mixing. The results of the chemical model with suppressed turbulent diffusion are close to those from the laminar model, but not completely. A simple analysis for the laminar chemical model to highlight potential sensitivity of a molecule to transport processes is performed. It is shown that the higher the ratio of the characteristic chemical timescale to the turbulent transport timescale for a given molecule, the higher the probability that its column density will be affected by diffusion. We find that turbulent transport enhances abundances and column densities of many gas-phase species and ices, particularly, complex ones. For such species a chemical steady-state is not reached due to long timescales associated with evaporation and surface photoprocessing and recombination ($t > 10^5$years). When a grain with an icy mantle is transported from a cold disk midplane into a warm intermediate/inner region, heavy radicals become mobile on the surface, enriching the mantle with complex ices, which are eventually released into the gas phase. The influence of turbulent mixing on disk chemistry is more pronounced in the inner, planet-forming disk region where gradients of temperature and high-energy radiation intensities are steeper than in the outer region. In contrast, simple radicals and molecular ions, which chemical evolution is fast and proceeds solely in the gas phase, are not much affected by dynamics. All molecules are divided into three groups according to the sensitivity of their column densities to the turbulent diffusion. The molecules that are unresponsive to transport include, e.g., C_2H, C^+, CH_4, CN, CO, HCN, HNC, H_2CO, OH, as well as water and ammonia ice. Their column densities computed with the laminar and 2D-mixing model differ by a factor of $\lesssim 2-5$ ("steadfast" species). Molecules which vertical column densities in the laminar and dynamical models differ by up to 2 order of magnitude include, e.g., C_2H_2, some carbon chains, CS, H_2CS, H_2O, HCO^+, HCOOH, HNCO, N_2H^+, NH_3, CO ice, H_2CO ice, CH_3OH ice, and electrons ("sensitive" species). Molecules which column densities are altered by diffusion by more than 2 orders of magnitude include, e.g., C_2S, C_3S, C_6H_6, CO_2, O_2, SiO, SO, SO_2, long carbon chain ices, CH_3CHO ice, HCOOH ice, O_2 ice, and OCN ice ("hypersensitive" species).
The chemical evolution of assorted molecules in the laminar and turbulent models is thouroughly analyzed and compared with previous studies. We find that column densities of observed gas-phase molecules in the DM Tau disk are well reproduced by both the laminar and the chemo-dynamical disk models. The observed abundances of many reduced and oxidized cometary ices are also successfully reproduced by the both models. We indicate several observable or potentially detectable tracers of transport processes in protoplanetary disks and the Solar nebula, e.g., elevated concentrations of heavy hydrocarbon ices, complex organics, CO_2, O_2, SO, SO_2, C_2S, C_3S compared to CO and the water ice. A combination of UV photodesorption, grain growth, and turbulent mixing leads to non-negligible amount of molecular gases in the cold disk midplane.

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Dust properties and disk structure of evolved protoplanetary disks in Cep OB2: Grain growth, settling, gas and dust mass, and inside-out evolution

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We present *Spitzer*/IRS spectra of 31 TTS and IRAM/1.3mm observations for 34 low- and intermediate-mass stars in the Cep OB2 region. Including our previously published data, we analyze 56 TTS and the 3 intermediate-mass stars with silicate features in Tr 37 (∼4 Myr) and NGC 7160 (∼12 Myr). The silicate emission features are well reproduced with a mixture of amorphous (with olivine, forsterite, and silica stoichiometry) and crystalline grains (forsterite, enstatite). We explore grain size and disk structure using radiative transfer disk models, finding that most objects have suffered substantial evolution (grain growth, settling). About half of the disks show inside-out evolution, with either dust-cleared inner holes or a radially-dependent dust distribution, typically with larger grains and more settling in the innermost disk. The typical strong silicate features require nevertheless the presence of small dust grains, and could be explained by differential settling according to grain size, anomalous dust distributions, and/or optically thin dust populations within disk gaps. M-type stars tend to have weaker silicate emission and steeper SEDs than K-type objects. The inferred low dust masses are in a strong contrast with the relatively high gas accretion rates, suggesting global grain growth and/or an anomalous gas to dust ratio. Transition disks (TD) in the Cep OB2 region display strongly processed grains, suggesting that they are dominated by dust evolution and settling. Finally, the presence of rare but remarkable disks with strong accretion at old ages reveals that some very massive disks may still survive to grain growth, gravitational instabilities, and planet formation.

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Turbulent Linewidths in Protoplanetary Disks: Predictions from Numerical Simulations

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Sub-mm observations of protoplanetary disks now approach the acuity needed to measure the turbulent broadening of molecular lines. These measurements constrain disk angular momentum transport, and furnish evidence of the turbulent environment within which planetesimal formation takes place. We use local magnetohydrodynamic (MHD) simulations of the magnetorotational instability (MRI) to predict the distribution of turbulent velocities in low mass protoplanetary disks, as a function of radius and height above the mid-plane. We model both ideal MHD disks, and disks in which Ohmic dissipation results in a dead zone of suppressed turbulence near the mid-plane. Under ideal conditions, the disk mid-plane is characterized by a velocity distribution that peaks near $v = 0.1c_s$ (where c_s is the local sound speed), while supersonic velocities are reached at $z > 3H$ (where H is the pressure scale height). Residual velocities of $v \sim 0.01c_s$ persist near the mid-plane in dead zones, while the surface layers remain active. Anisotropic variation of the linewidth with disk inclination is modest. We compare our MHD results to hydrodynamic simulations in which large-scale forcing is used to initiate similar turbulent velocities. We show that the qualitative trend of increasing v with height, seen in the MHD case, persists for forced turbulence and is likely a generic property of disk turbulence. Percent level determinations of v at different heights within the disk, or spatially resolved observations that probe the inner disk containing the dead zone region, are therefore needed to test whether the MRI is responsible for protoplanetary disk turbulence.

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Measured Diameters of Two F-stars in the Beta Pic Moving Group

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We report angular diameters of HIP 560 and 21547, two F spectral type pre-main sequence members of the β Pic Moving Group. We used the East-West 314-m long baseline of the CHARA Array. The measured limb-darkened angular diameters of HIP 560 and 21547 are 0.492 ± 0.032 and 0.518 ± 0.009 mas, respectively. The corresponding

stellar radii are 2.1 and 1.6 $R_\odot$ for HIP 560 and HIP 21547 respectively. These values indicate that the stars are truly young. Analyses using the evolutionary tracks calculated by Siess, Dufour, and Forestini and the tracks of the Yonsei-Yale group yield consistent results. Analyzing the measurements on an angular diameter *vs* color diagram we find that the ages of the two stars are indistinguishable; their average value is 13 ± 2 MY. The masses of HIP 560 and 21547 are 1.65 ± 0.02 and 1.75 ± 0.05 $M_\odot$, respectively. However, analysis of the stellar parameters on a Hertzsprung-Russell Diagram yields ages at least 5 MY older. Both stars are rapid rotators. The discrepancy between the two types of analyses has a natural explanation in gravitational darkening. Stellar oblateness, however, does not affect our measurements of angular diameters.

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A Spitzer Space Telescope survey of massive young stellar objects in the G333.2-0.4 giant molecular cloud

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The G333 giant molecular cloud contains a few star clusters and H II regions, plus a number of condensations currently forming stars. We have mapped thirteen of these sources with the appearance of young stellar objects (YSOs) with the Spitzer Infrared Spectrograph in the Short-Low, Short-High, and Long-High modules (5-36 micron). We use these spectra plus available photometry and images to characterize the YSOs. The spectral energy distributions (SEDs) of all sources peak between 35 and 110 micron, thereby showing their young age. The objects are divided into two groups: YSOs associated with extended emission in IRAC band 2 at 4.5 micron ('outflow sources') and YSOs that have extended emission in all IRAC bands peaking at the longest wavelengths ('red sources'). The two groups of objects have distinctly different spectra: All the YSOs associated with outflows show evidence of massive envelopes surrounding the protostar because the spectra show deep silicate absorption features and absorption by ices at 6.0, 6.8, and 15.2 micron. We identify these YSOs with massive envelopes cool enough to contain ice-coated grains as the 'bloated' protostars in the models of Hosokawa et al. All spectral maps show ionized forbidden lines and polycyclic aromatic hydrocarbon emission features. For four of the red sources, these lines are concentrated to the centres of the maps, from which we infer that these YSOs are the source of ionizing photons. Both types of objects show evidence of shocks, with most of the outflow sources showing a line of neutral sulphur in the outflows and two of the red sources showing the more highly excited [Ne III] and [S IV] lines in outflow regions at some distance from the YSOs. The 4.5 micron emission seen in the IRAC band 2 images of the outflow sources is not due to H2 lines, which are too faint in the 5 - 10 micron wavelength region to be as strong as is needed to account for the IRAC band 2 emission.

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Correlating the interstellar magnetic field with protostellar jets and its sources

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This article combines new CCD polarimetric data with previous information about protostellar objects in a search for correlations involving the interstellar magnetic field. Specifically, we carried out an optical polarimetric study of a sample of 28 fields of 10×10 arcmin^2 located in the neighborhood of protostellar jets and randomly spread over the Galaxy. The polarimetry of a large number of field stars is used to estimate both the average and dispersion of the interstellar magnetic field (ISMF) direction in each region. The results of the applied statistical tests are as follows. Concerning the alignment between the jet direction and the interstellar magnetic field, the whole sample does not show alignment. There is, however, a statistically significant alignment for objects of Classes 0 and I. Regarding the interstellar magnetic field dispersion, our sample presents values slightly larger for regions containing T Tauri objects than for those harboring younger protostars. Moreover the ISMF dispersion in regions containing high-mass objects tends to be larger than in those including only low-mass protostars. In our sample, the mean interstellar polarization as a function of the average interstellar extinction in a region reaches a maximum value around 3% for A(V) = 5, after which it decreases. Our data also show a clear correlation of the mean value of the interstellar polarization with the dispersion of the interstellar magnetic field: the larger the dispersion, the smaller the polarization. Based on a comparison of our and previous results, we suggest that the dispersion in regions forming stars is larger than in quiescent regions.

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Protoplanets with core masses below the critical mass fill in their Roche lobe

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We study the evolution of a protoplanet of a few earth masses embedded in a protoplanetary disc. If we assume that the atmosphere of the protoplanet, i.e. the volume of gas in hydrostatic equilibrium bound to the core, has a surface radius smaller than the Roche lobe radius, we show that it expands as it accretes both planetesimals and gas at a fixed rate from the nebula until it fills in the Roche lobe. The evolution occurs on a timescale shorter than the formation or migration timescales. Therefore, we conclude that protoplanets of a few earth masses have an atmosphere that extends to the Roche lobe surface, where it matches to the nebula. This is true even when the Bondi radius is smaller than the Roche lobe radius. This is in contrast to the commonly used models in which the static atmosphere extends up to the Bondi radius and is surrounded by a cold accretion flow. As a result, any calculation of the tidal torque exerted by the disc onto the protoplanet should exclude the material present in the Roche lobe, since it is bound to the protoplanet.

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Jet formation from massive young stars: Magnetohydrodynamics versus radiation pressure

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Observations indicate that outflows from massive young stars are more collimated during their early evolution compared to later stages. Our paper investigates various physical processes that impacts the outflow dynamics, i.e. its acceleration and collimation. We perform axisymmetric MHD simulations particularly considering the radiation pressure exerted by the star and the disk. We have modified the PLUTO code to include radiative forces in the line-driving approximation. We launch the outflow from the innermost disk region ($r < 50\,\mathrm{AU}$) by magneto-centrifugal acceleration. In order to disentangle MHD effects from radiative forces, we start the simulation in pure MHD, and later switch on the radiation force. We perform a parameter study considering different stellar masses (thus luminosity), magnetic flux, and line-force strength. For our reference simulation - assuming a $30\,\mathrm{M}_{\odot}$ star, we find substantial de-collimation of 35% due to radiation forces. The opening angle increases from 20° to 32° for stellar masses from $20\,\mathrm{M}_{\odot}$ to $60\,\mathrm{M}_{\odot}$. A small change in the line-force parameter α from 0.60 to 0.55 changes the opening angle by $\sim 8°$. We find that it is mainly the stellar radiation which affects the jet dynamics. Unless the disk extends very close to the star, its pressure

is too small to have much impact. Essentially, our parameter runs with different stellar mass can be understood as a proxy for the time evolution of the star-outflow system. Thus, we have shown that when the stellar mass (thus luminosity) increases (with age), the outflows become less collimated.

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The chemical history of molecules in circumstellar disks. II. Gas-phase species

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Context: The chemical composition of a molecular cloud changes dramatically as it collapses to form a low-mass protostar and circumstellar disk. Two-dimensional (2D) chemodynamical models are required to properly study this process.
Aims: The goal of this work is to follow, for the first time, the chemical evolution in two dimensions all the way from a pre-stellar core into a circumstellar disk. Of special interest is the question whether the chemical composition of the disk is a result of chemical processing during the collapse phase, or whether it is determined by in situ processing after the disk has formed.
Methods: Our model combines a semi-analytical method to get 2D axisymmetric density and velocity structures with detailed radiative transfer calculations to get temperature profiles and UV fluxes. Material is followed in from the core to the disk and a full gas-phase chemistry network – including freeze-out onto and evaporation from cold dust grains – is evolved along these trajectories. The abundances thus obtained are compared to the results from a static disk model and to observations of comets.
Results: The chemistry during the collapse phase is dominated by a few key processes, such as the evaporation of CO or the photodissociation of H_2O. Depending on the physical conditions encountered along specific trajectories, some of these processes are absent. At the end of the collapse phase, the disk can be divided into zones with different chemical histories. The disk is not in chemical equilibrium at the end of the collapse, so care must be taken when choosing the initial abundances for stand-alone disk chemistry models. Our model results imply that comets must be formed from material with different chemical histories: some of it is strongly processed, some of it remains pristine. Variations between individual comets are possible if they formed at different positions or different times in the solar nebula.

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Kinematics and Physical Conditions of the Innermost Envelope in B335

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We made $C^{18}O$ (2–1) and CS (7–6) images of the protostellar envelope around B335 with a high spatial dynamic range from ∼10000 to ∼400 AU, by combining the Submillimeter Array and single-dish data. The $C^{18}O$ emission shows an extended (∼10000 AU) structure as well as a compact (∼1500 AU) component concentrated at the protostellar position. The CS emission shows a compact (∼900 AU) component surrounding the protostar, plus a halo-like (∼3000 AU) structure elongated along the east-west direction. At higher velocities ($|\Delta V| \gtrsim 0.3$ km s^{-1}), the CS emission is stronger and more extended than the $C^{18}O$ emission. Physical conditions of the envelope were examined through an LVG model. At $|\Delta V| \gtrsim 0.3$ km s^{-1}, the gas temperature is higher (>40 K) than that at $|\Delta V| \lesssim 0.3$ km s^{-1}, whereas the gas density is lower ($<10^6$ cm^{-3}). We consider that the higher-temperature and lower-density gas at $|\Delta V| \gtrsim 0.3$ km s^{-1} is related to the associated outflow, while the lower-temperature and higher-density gas at $|\Delta V| \lesssim 0.3$ km s^{-1}

is the envelope component. From the inspection of the positional offsets in the velocity channel maps, the radial profile of the specific angular momentum of the envelope rotation in B335 was revealed at radii from $\sim 10^4$ down to $\sim 10^2$ AU. The specific angular momentum decreases down to the radius of $\sim$370 AU, and then appears to be conserved within that radius. A possible scenario of the evolution of envelope rotation is discussed.

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The outcome of protoplanetary dust growth: pebbles, boulders, or planetesimals? III. Sedimentation driven coagulation inside the snow-line

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The evolution of dust particles in protoplanetary disks determines many observable and structural properties of the disk, such as the spectral energy distribution (SED), appearance of disks, temperature profile, and chemistry. Dust coagulation is also the first step towards planet formation.

We investigate dust growth due to settling in a 1D vertical column of a disk. It is known from the ten micron feature in disk SEDs, that small micron-sized grains are present at the disk atmosphere throughout the lifetime of the disk. We hope to explain such questions as what process can keep the disk atmospheres dusty for the lifetime of the disk and how the particle properties change as a function of height above the midplane.

We used a Monte Carlo code to follow the mass and porosity evolution of the particles in time. We gradually build up the complexity of the models by considering the effects of porosity, different collision models, turbulence, and different gas models, respectively. This way we can distinguish the effects of these physical processes on particle growth and motion. The collision model used is based on laboratory experiments performed on dust aggregates. As the experiments cannot cover all possible collision scenarios, the largest uncertainty of our model comes from the necessary extrapolations we had to perform. We simultaneously solved for the particle growth and motion. Particles can move vertically due to settling and turbulent mixing. We assumed that the vertical profile of the gas density is fixed in time and that only the solid component evolves.

We find that the used collision model strongly influences the masses and sizes of the particles. The laboratory-experiment based collision model greatly reduces the particle sizes compared to models that assume sticking at all collision velocities. We find that a turbulence parameter of $\alpha = 10^{-2}$ is needed to keep the dust atmospheres dusty, but such strong turbulence can produce only small particles at the midplane, which does not favor for planetesimal formation models. We also see that the particles are larger at the midplane and smaller at the upper layers of the disk. At 3-4 pressure-scale heights, micron-sized particles are produced. These particle sizes are needed to explain the ten micron feature of disk SEDs. Turbulence may therefore help keep small dust particles in the disk atmosphere.

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Chemical evolution of a protoplanetary disk

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In this paper we review recent progress in our understanding of the chemical evolution of protoplanetary disks. Current observational constraints and theoretical modeling on the chemical composition of gas and dust in these systems are presented. Strong variations of temperature, density, high-energy radiation intensities in these disks, both radially and vertically, result in a peculiar disk chemical structure, where a variety of processes are active. In hot, dilute and heavily irradiated atmosphere only the most photostable simple radicals and atoms and atomic ions exist, formed by gas-phase processes. Beneath the atmosphere a partly UV-shielded, warm molecular layer is located, where high-energy radiation drives rich ion-molecule and radical-radical chemistry, both in the gas phase and on dust surfaces. In a cold, dense, dark disk midplane many molecules are frozen out, forming thick icy mantles where surface chemistry is active and where complex polyatomic (organic) species are synthesized. Dynamical processes affect disk chemical composition by enriching it in abundances of complex species produced via slow surface processes, which will become detectable with ALMA.

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Observational Constraints on the Evolution of Dust in Protoplanetary Disks

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This thesis presents unbiased surveys of low-mass young stars and their dusty disks in nearby star-forming regions using *Spitzer* and optical telescopes to probe the evolution of dust in protoplanetary disks. It addresses the full star-disk system: the stellar characteristics and their effect on disk evolution, as well as the changes taking place in the dust by making use of statistically relevant samples.

Optical spectroscopic surveys designed to characterize the new young stellar populations in the Serpens Molecular Cloud and the Lupus Clouds, as found by the *Spitzer* c2d program, are presented. Spectral types and effective temperatures are derived, and are combined with optical and IR photometry to calculate the stellar luminosities, which allows placement of these stars in a H-R diagram. Various methods are devised to distinguish true young stellar objects in the cloud from other reddened sources. Aided by evolutionary stellar tracks, ages in the range of 1–3 Myr and masses of 0.2–1.2 $M_\odot$ are inferred for the stars belonging to Serpens (taking d = 415 pc). The Lupus sample consists consists mostly of cooler, late-type M stars (90%). According to theoretical evolutionary models overlaid on H-R diagrams, the population is ∼2 Myr old, with a mean mass of only 0.2 $M_\odot$. Furthermore, mass accretion rates are estimated from the full width at 10% of peak intensity of the Hα line in emission, showing distributions typical of T Tauri stars ($10^{-6} - 10^{-11} M_\odot$ yr^{-1}) for both clouds, with a large scatter.

A complete sample of flux-limited *Spitzer* IRS mid-IR (5–35 μm) spectra of the young stellar population of Serpens is presented and extensively studied. The objects are classified according to their spectra, into background contamination (stars, galaxies and a new dusty planetary nebula) and young stars belonging to the cloud. The bona fide YSOs amount to 115 objects, comprising embedded (class I, 18%) and disk (classes II and III, 82%) sources. Inner disk geometry is inferred from the flux ratio between 30 and 13 μm. About 8% of the disks have 30/13 ?m flux ratios consistent with cold disks with inner holes or gaps, and only 3% of the disks show PAH emission. The silicate features at 10 and 20 μm are strongly affected by the size of its emitting dust and therefore used as a proxy for dust size. A population of small dust grains is maintained in the surface layers of the disks independent of inner disk geometry, or of a clustered or isolated environment. Additionally, the distribution of silicate feature shapes and strengths from Serpens are found to be similar to those found in Taurus and the c2d sample distributed over 5 clouds. This result implies that the dust population in the surface of disks arises from an equilibrium between particle growth and fragmentation, independent of environment. This equilibrium is maintained for as long as the disks are optically thick at optical and infrared wavelengths.

Furthermore, the dust mineralogy in the disk surface has been derived and compared for four clusters for which complete IRS samples exist: the young Serpens and Taurus samples, as well as the Upper Scorpius and η Chamaeleontis clusters which probe the older bin of disk evolution. The data are analyzed with the same techniques, allowing direct comparison of results. A similar distribution of mean mass-averaged grain sizes (few μm) and crystallinity fractions ($\sim 10 - 20\%$) is observed for the four regions, despite different mean cluster ages and disk fractions. The wide spread in cluster ages (∼1–8 Myr) and disk geometries, without concurrent evolution of the disk surface dust properties, points to a rapid change taking place early ($\leq$1 Myr) and an equilibrium such that these properties are statistically the same until disk dissipation.

http://www.strw.leidenuniv.nl/events/phdtheses/oliveira/

Assistant Scientist
Department of Astronomy
University of Florida

The Department of Astronomy at the University of Florida is seeking an Assistant Scientist in observational star formation. This is full-time 9-month time limited non-tenure accruing position. The successful applicant will perform research on embedded clusters and participate in an educational outreach program at local middle and elementary schools in the Gainesville, Florida, area. The research activities will involve planning and execution of near-IR spectroscopic observations, reduction and interpretation of data obtained with FLAMINGOS and Spitzer, classification of near-IR stellar spectra and mid-IR SED's and the publication and presentation of results.

Strong preference will be given to candidates having experience with near-IR spectral classification of young stars and experience observing, reducing and analyzing FLAMINGOS data. In addition, candidates should have expertise in obtaining, reducing and analyzing mid-infrared observations and the infrared classification of circumstellar disks. A Ph.D. in Astronomy with postdoctoral experience is required. The starting date for this position will be as soon as possible, preferably by October 3, 2011. Salary will be commensurate with qualifications and experience. Review of applications will begin immediately and will continue until the position is filled.

Candidates must apply online at http://jobs.ufl.edu (requisition # 0809330).For full consideration, interested applicants must submit online application, cover letter referencing PeopleSoft position number 00026743, Curriculum Vitae, and have three letters of recommendation sent to Dr. Elizabeth Lada, Ph.D., Chair of Search Committee, Department of Astronomy, PO Box 112055, Gainesville, FL 32611. The University of Florida is an equal opportunity institution dedicated to building a broadly diverse and inclusive faculty and staff.

Postdoctoral Fellowship: Brewing Great Science with MALT90

Applications are invited for a three-year post-doctoral OCE fellowship at the CSIRO Astronomy and Space Science (CASS) - Australia Telescope National Facility to conduct new and exciting research in the field of high-mass star-formation utilizing data from the Millimetre Astronomy Legacy Team 90 GHz (MALT90) survey. MALT90 is a large international project aimed at characterizing high-mass dense cores. When complete, MALT90 will be the largest database of molecular line emission toward high-mass star-forming cores.

The Australia Telescope National Facility is Australia's premier radio astronomical facility, operating three world-class radio telescopes, the Parkes 64-m, the 6-element Australia Telescope Compact Array at Narrabri, and the Mopra 22-m. CSIRO is also currently constructing the Australian SKA Pathfinder (ASKAP) in Western Australia, to begin observations in 2013. ASKAP will be the world's best wide-field survey telescope for radio astronomy.

We are seeking a motivated postdoctoral researcher to join CASS to drive scientific output and follow-up projects that fully exploit the MALT90 dataset. The post-doc will also have an opportunity to pursue a strong independent research programme in high-mass star formation studies using CSIRO's Australia Telescope Compact Array (ATCA) and the upcoming multi-billion dollar Atacama Large Millimetre Array (ALMA).

The position will be for three years starting in 2012, the exact start date is negotiable. The position will be based at the headquarters of CASS in vibrant Sydney, Australia.

Inquiries can be emailed to Dr Jill Rathborne at Jill.Rathborne *at* csiro.au

For essential information and details on how to apply, please visit www.csiro.au/careers and in "Positions Vacant" search for job number "NSW00967".

Applications close: 15 November 2011.

Australis Fellowship - Joint Postdoctoral Position with CSIRO Astronomy and Space Science and Universidad de Chile in the field of high-mass star formation

The CSIRO Astronomy and Space Science (CASS) and the Department of Astronomy at the Universidad de Chile (DAUCH) invite applications for a joint post-doctoral research position (Australis Fellowship) in the field of star formation. The successful applicant is expected to conduct independent research and to collaborate with Dr. Kate Brooks, Dr. Jill Rathborne (CASS), Dr. Diego Mardones and Dr. Guido Garay (DAUCH) on studies of high-mass star-formation using centimeter, millimeter, sub-millimeter, and infrared data.

The Australis Fellow is expected to spend half of the time in Santiago, Chile, at the DAUCH, and half of the time in Sydney, Australia at the CASS Australia Telescope National Facility (ATNF) Headquarters. ATNF is Australia's premier radio astronomical facility and operates the Australia Telescope Compact Array (ATCA), the Mopra 22-m telescope, the Parkes 64-m telescope, and the Long Baseline Array (LBA). These facilities provide opportunities for world-class radio astrophysics in the frequency range of 1-115 GHz. Construction is now underway of the Australian Square Kilometre Array Pathfinder (ASKAP), a powerful new instrument for high dynamic range, ultra-wide-field radio astronomy between 0.7 and 1.8 GHz that will be sited in Western Australia at the Australian SKA candidate site and be operational in 2013.

For the duration of the Fellowship the appointee will have access to the 10% observing time reserved for Chilean astronomers on all astronomical facilities in Chile, including ALMA, APEX and ASTE.

The Australis Fellowship is awarded for a two-year period, renewable for a third, and offers a competitive salary with benefits as well as additional funding for travel. The position will commence in 2012; the exact start date and location are negotiable. Candidates are strongly encouraged to consider spending the first year of the fellowship in Chile. Candidates must hold a Ph.D. in astronomy or related field by date of appointment. Owing to terms of the fellowship, candidates must not have more than 3 years of relevant postdoctoral experience.

Applications should consist of a cover letter, curriculum vitae, publication list, and a 3-page description of research accomplishments and future research plans. The research plan should outline the candidate's future research directions on how to best utilize the facilities within Chile and Australia. The application should arrive by December 1, 2011. Applicants should also arrange for three letters of recommendation to arrive by the same date. Email submission of all materials, including letters, to Prof. Rene Mendez, Chair, Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Correo Central, Santiago, Chile (rmendez *at* das.uchile.cl).

E-mail inquiries can be sent to: Kate.Brooks *at* csiro.au, Jill.Rathborne *at* csiro.au, dmardone *at* das.uchile.cl or guido *at* das.uchile.cl

Astrophysics at Extremely High Angular Resolution: Optical and Infrared Interferometry

We'd like to announce a one day RAS Specialist Discussion meeting on

Astrophysics at Extremely High Angular Resolution: Optical and Infrared Interferometry

Friday 11 November, 10:30 - 15:30

The Geological Society, Burlington House, LONDON, W1J 0BG, UK

The new century has seen a quantum leap in the field of optical and infrared long-baseline interferometry, with facilities such as the CHARA and VLTI arrays now routinely producing images with milliarcsecond resolution. As a result, over the past ten years, ground-based optical/IR interfometry has transitioned to become a mainstream, common-user, technique offering unprecedented insights into a wide range of astrophysical phenomena. These include asteroseismology, YSO accretion, photosphere dynamics, exoplanet characterization, and the structure of AGN cores.

This meeting will bring together experts and novices in the field to present their latest scientific results, and to highlight the existing and upcoming capabilities at facility class arrays such as the VLTI. We hope to attract not only attendees who are excited by the possibilities that interferometric methods can bring to their research, but also those who wish to find out more and assess the investment of their time needed to best exploit the UK's access to European and American interferometric arrays.

You can find more information, including a preliminary program on http://www.ast.leeds.ac.uk/∼roud/rasmeet2012.htm

Rene Oudmaijer (Leeds) r.d.oudmaijer at leeds.ac.uk

Ettore Pedretti (St Andrews, ESO) ep41 at st-and.ac.uk

Chris Haniff (Cambridge) cahm at rao.cam.ac.uk

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.