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Abstracts of recently accepted papers

Sub-arcsecond [FeII] spectro-imaging of the DG Tau jet: Periodic bubbles and a dusty disk wind?

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Context: The origin of protostellar jets as well as their impact on the regulation of angular momentum and the inner disk physics are still crucial open questions in star formation.
Aims: We aim to test the different proposed ejection processes in T Tauri stars through high-angular resolution observations of forbidden-line emission from the inner DG Tauri microjet.
Methods: We present spectro-imaging observations of the DG Tauri jet obtained with SINFONI/VLT in the lines of [Fe II]λ1.64 μm, 1.53μm with $0\farcs15$ angular resolution and R=3000 spectral resolution. We analyze the morphology and kinematics, derive electronic densities and mass-flux rates and discuss the implications for proposed jet launching models.
Results: (1) We observe an onion-like velocity structure in [Fe II] in the blueshifted jet, similar to that observed in optical lines. High-velocity (HV) gas at $\simeq$ -200 km s^{-1} is collimated inside a half-opening angle of 4° and medium-velocity (MV) gas at $\simeq$ -100 km s^{-1}in a cone with an half-opening angle 14°. (2) Two new axial jet knots are detected in the blue jet, as well as a more distant bubble with corresponding counter-bubble. The periodic knot ejection timescale is revised downward to 2.5 yrs. (3) The redshifted jet is detected only beyond $0\farcs7$ from the star, yielding revised constraints on the disk surface density. (4) From comparison to [O I] data we infer iron depletion of a factor 3 at high velocities and a factor 10 at speeds below -100 km s^{-1}. (5) The mass-fluxes in each of the medium and high-velocity components of the blueshifted lobe are $\simeq 1.6 \pm 0.8 \times 10^{-8}$ M$_\odot$ yr^{-1}, representing 0.02–0.2 of the disk accretion rate.
Conclusions: The medium-velocity conical [Fe II] flow in the DG Tau jet is too fast and too narrow to trace photo-evaporated matter from the disk atmosphere. Both its kinematics and collimation cannot be reproduced by the X-wind, nor can the "conical magnetospheric wind". The level of Fe gas phase depletion in the DG Tau medium-velocity component also rules out a stellar wind and a cocoon ejected sideways from the high-velocity beam. A quasi-steady centrifugal MHD disk wind ejected over 0.25–1.5 AU and/or episodic magnetic tower cavities launched from the disk appear as the most plausible origins for the [Fe II] medium velocity component in the DG Tau jet. The same disk wind model can also account for the properties of the high-velocity [Fe II] flow, although alternative origins in magnetospheric and/or stellar winds cannot be excluded for this component.

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The First X-shooter Observations of Jets from Young Stars

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We present the first pilot study of jets from young stars conducted with X-shooter, on ESO/VLT. As it offers simultaneous, high quality spectra in the range 300-2500 nm X-shooter is uniquely important for spectral diagnostics in jet studies. We chose to probe the accretion/ejection mechanisms at low stellar masses examining two targets with well resolved continuous jets lying on the plane of the sky, ESO-HA 574 in Chamaeleon I, and Par-Lup3-4 in Lupus III. The mass of the latter is close to the sub-stellar boundary ($M_\star$=0.13 $M_\odot$). A large number of emission lines probing regions of different excitation are identified, position-velocity diagrams are presented and mass outflow/accretion rates are estimated. Comparison between the two objects is striking. ESO-HA 574 is a weakly accreting star for which we estimate a mass accretion rate of $log(\dot{M}_{acc}) = -10.8 \pm 0.5$ (in $M_\odot$ yr^{-1}), yet it drives a powerful jet with $\dot{M}_{out} \sim 1.5 - 2.7 \times 10^{-9}$ $M_\odot$ yr^{-1}.These values can be reconciled with a magneto-centrifugal jet acceleration mechanism only assuming that the presence of the edge-on disk severely depresses the luminosity of the accretion tracers. In comparison Par-Lup3-4 with stronger mass accretion ($log(\dot{M}_{acc}) = -9.1 \pm 0.4$ $M_\odot$ yr^{-1}), drives a low excitation jet with about $\dot{M}_{out} \sim 3.2 \times 10^{-10}$ $M_\odot$ yr^{-1} in both lobes. Despite the low stellar mass, $\dot{M}_{out}/\dot{M}_{acc}$ for Par-Lup3-4 is at the upper limit of the range usually measured for young objects, but still compatible with a steady magneto-centrifugal wind scenario if all uncertainties are considered.

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Gravity or turbulence? II. Evolving column density PDFs in molecular clouds

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It has been recently shown that molecular clouds do not exhibit a unique shape for the column density probability distribution function (N-PDF). Instead, clouds without star formation seem to possess a lognormal distribution, while clouds with active star formation develope a power-law tail at high column densities. The lognormal behavior of the N-PDF has been interpreted in terms of turbulent motions dominating the dynamics of the clouds, while the power-law behavior occurs when the cloud is dominated by gravity. In the present contribution we use thermally bi-stable numerical simulations of cloud formation and evolution to show that, indeed, these two regimes can be understood in terms of the formation and evolution of molecular clouds: a very narrow lognormal regime appears when the cloud is being assembled. However, as the global gravitational contraction occurs, the initial density fluctuations are enhanced, resulting, first, in a wider lognormal N-PDF, and later, in a power-law N-PDF. We thus suggest that the observed N-PDF of molecular clouds are a manifestation of their global gravitationally contracting state. We also show that, contrary to recent suggestions, the exact value of the power-law slope is not unique, as it depends on the projection in which the cloud is being observed.

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The Galactic Census of High- and Medium-mass Protostars. I. Catalogues and First Results from Mopra HCO^+ Maps

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The *Census of High- and Medium-mass Protostars* (CHaMP) is the first large-scale, unbiased, uniform mapping survey at sub-parsec scale resolution of 90 GHz line emission from massive molecular clumps in the Milky Way. We present the first Mopra (ATNF) maps of the CHaMP survey region ($300°>l>280°$) in the HCO^+ J=1→0 line, which is usually thought to trace gas at densities up to 10^{11}m^{-3}. In this paper we introduce the survey and its strategy, describe the observational and data reduction procedures, and give a complete catalogue of moment maps of the HCO^+ J=1→0 emission from the ensemble of 303 massive molecular clumps. From these maps we also derive the physical parameters of the clumps, using standard molecular spectral-line analysis techniques. This analysis yields the following range of properties: integrated line intensity 1–30 Kkm s^{-1}, peak line brightness 1–7 K, linewidth 1–10km s^{-1}, integrated line luminosity 0.5–200 Kkm s^{-1} pc^2, FWHM size 0.2–2.5 pc, mean projected axial ratio 2, optical depth 0.08–2, total surface density 30–3000 M$_\odot$ pc^{-2}, number density 0.2–30×10^9 m^{-3}, mass 15–8000 M$_\odot$, virial parameter 1–55, and total gas pressure 0.3–700 pPa. We find that the CHaMP clumps do not obey a Larson-type size-linewidth relation. Among the clumps, there exists a large population of subthermally excited, weakly-emitting (but easily detectable) dense molecular clumps, confirming the prediction of Narayanan et al (2008). These weakly-emitting clumps comprise 95% of all massive clumps by number, and 87% of the molecular mass, in this portion of the Galaxy; their properties are distinct from the brighter massive star-forming regions that are more typically studied. If the clumps evolve by slow contraction, the 95% of fainter clumps may represent a long-lived stage of pressure-confined, gravitationally stable massive clump evolution, while the CHaMP clump population may not engage in vigorous massive star formation until the last 5% of their lifetimes. The brighter sources are smaller, denser, more highly pressurised, and closer to gravitational instability than the less bright sources. Our data suggest that massive clumps approach critical Bonnor-Ebert like states at constant density, while others' suggest that lower-mass clumps reach such states at constant pressure. Evidence of global gravitational collapse of massive clumps is rare, suggesting this phase lasts <1% of the clumps' lifetime.

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http://www.astro.ufl.edu/∼peterb/research/champ/papers

A low optical depth region in the inner disk of the Herbig Ae star HR5999

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Circumstellar disks surrounding young stars are known to be the birthplaces of planetary systems, and the innermost astronomical unit is of particular interest. Near-infrared interferometric studies have revealed a complex morphology for the close environment surrounding Herbig Ae stars. In this paper, we present new long-baseline spectro-interferometric observations of the Herbig Ae star, HR 5999, obtained in the H and K bands with the AMBER instrument at the VLTI, and aim to produce near-infrared images at the sub-AU spatial scale.

We spatially resolve the circumstellar material and reconstruct images in the H and K bands using the MiRA algorithm. In addition, we interpret the interferometric observations using models that assume that the near-infrared excess is dominated by the emission of a circumstellar disk. We compare the images reconstructed from the VLTI measurements to images obtained using simulated model data.
The K-band image reveals three main elements: a ring-like feature located at ∼0.65 AU, a low surface brightness region inside 0.65 AU, and a central spot. At the maximum angular resolution of our observations (B/λ ∼1.3 mas), the ring is resolved while the central spot is only marginally resolved, preventing us from revealing the exact morphology of the circumstellar environment. We suggest that the ring traces silicate condensation, i.e., an opacity change, in a circumstellar disk around HR 5999. We build a model that includes a ring at the silicate sublimation radius and an inner disk of low surface brightness responsible for a large amount of the near-infrared continuum emission. The model successfully fits the SED, visibilities, and closure phases in the H and K bands, and provides evidence of a low surface brightness region inside the silicate sublimation radius.
This study provides milli-arcsecond resolution images of the environment of HR 5999 and additional evidence that in Herbig Ae stars, there is material in a low surface brightness region, probably a low optical depth region, located inside the silicate sublimation radius and of unknown nature. The possibility that the formation of such a region in a thick disk is related to disk evolution should be investigated.

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First Results from a 1.3 cm EVLA Survey of Massive Protostellar Objects: G35.03+0.35

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We have performed a 1.3 cm survey of 24 massive young stellar objects (MYSOs) using the Expanded Very Large Array (EVLA). The sources in the sample exhibit a broad range of massive star formation signposts including Infrared Dark Clouds (IRDCs), UCHII regions, and extended 4.5μm emission in the form of Extended Green Objects (EGOs). In this work, we present results for G35.03+0.35 which exhibits all of these phenomena. We simultaneously image the 1.3 cm NH_3 (1,1) through (6,6) inversion lines, four CH_3OH transitions, two H recombination lines, plus continuum at 0.05 pc resolution. We find three areas of thermal NH_3 emission, two within the EGO (designated the NE and SW cores) and one toward an adjacent IRDC. The NE core contains an UCH II region (CM1) and a candidate HCH II region (CM2). A region of non-thermal, likely masing NH_3 (3,3) and (6,6) emission is coincident with an arc of 44 GHz CH_3OH masers. We also detect two new 25 GHz Class I CH_3OH masers. A complementary Submillimeter Array 1.3 mm continuum image shows that the distribution of dust emission is similar to the lower-lying NH_3 lines, all peaking to the NW of CM2, indicating the likely presence of an additional MYSO in this protocluster. By modeling the NH_3 and 1.3 mm continuum data, we obtain gas temperatures of 20-220 K and masses of 20-130 $M_\odot$. The diversity of continuum emission properties and gas temperatures suggest that objects in a range of evolutionary states exist concurrently in this protocluster.

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Star formation in bright-rimmed clouds and cluster associated with W5 E H II region

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The aim of this paper is to present the results of photometric investigations of the central cluster of the W5 E region as well as a follow-up study of the triggered star formation in and around bright-rimmed clouds (BRCs). We have carried out wide field $UBVI_c$ and deep VI_c photometry of the W5 E HII region. A distance of ∼2.1 kpc and a mean age of ∼1.3 Myr have been obtained for the central cluster. The young stellar objects (YSOs) associated with the region are identified on the basis of near-infrared and mid-infrared observations. We confirmed our earlier results that the average age of the YSOs lying on/inside the rim are younger than those lying outside the rim. The global distribution of the YSOs shows an aligned distribution from the ionising source to the BRCs. These facts indicate that a series of radiation driven implosion processes proceeded from near the central ionising source towards the periphery of the W5 E HII region. We found that, in general, the age distributions of the Class II and Class III sources are the same. This result is apparently in contradiction with the conclusion by Bertout, Siess & Cabrit (2007) and Chauhan et al. (2009) that classical T Tauri stars evolve to weak-line T Tauri stars. The initial mass function of the central cluster region in the mass range $0.4 \leq M/M_{\odot} \leq 30$ can be represented by $\Gamma = -1.29 \pm 0.04$. The cumulative mass functions indicate that in the mass range $0.2 \leq M/M_{\odot} \leq 0.8$, the cluster region and BRC NW have more low mass YSOs in comparison to BRCs 13 and 14.

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Stars at the Tip of Peculiar Elephant Trunk-Like Clouds in IC 1848E: A Possible Third Mechanism of Triggered Star Formation

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The HII region IC 1848 harbors a lot of intricate elephant trunk-like structures that look morphologically different from usual bright-rimmed clouds (BRCs). Of particular interest is a concentration of thin and long elephant trunk-like structures in the southeastern part of IC 1848E. Some of them have an/a few apparently associated star/stars at their very tip. We made VI_c photometry of several of these stars. Their positions on the $V/V - I_c$ color-magnitude diagram as well as the physical parameters obtained by SED fittings indicate that they are low-mass pre-main sequence stars of ages of mostly one *Myr* or less. This strongly suggests that they formed from the elongated, elephant trunk-like clouds. We presume that such elephant trunk-like structures are genetically different from BRCs, on the basis of the differences in morphology, size distributions, and the ages of the associated young stars. We suspect that those clouds have been caused by hydrodynamical instability of the ionization/shock front of the expanding HII region. Similar structures often show up in recent numerical simulations of the evolution of HII regions. We further hypothesize that this mechanism makes a third mode of triggered star formation associated with HII regions, in addition to the two known mechanisms, i.e., *collect-and-collapse* of the shell accumulated around an expanding HII region and *radiation-driven implosion* of BRCs originated from pre-existing cloud clumps.

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Jet rotation driven by MHD shocks in helical magnetic fields

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In this paper we present a detailed numerical investigation of the hypothesis that a rotation of astrophysical jets can be caused by magnetohydrodynamic shocks in a helical magnetic field.
Shock compression of the helical magnetic field results in a toroidal Lorentz force component which will accelerate the jet material in toroidal direction. This process transforms magnetic angular momentum (magnetic stress) carried along the jet into kinetic angular momentum (rotation). The mechanism proposed here only works in a *helical* magnetic

field configuration.
We demonstrate the feasibility of this mechanism by axisymmetric MHD simulations in 1.5D and 2.5D using the PLUTO code. In our setup the jet is injected into the ambient gas with zero kinetic angular momentum (no rotation). Different dynamical parameters for jet propagation are applied such as the jet internal Alfvén Mach number and fast magnetosonic Mach number, the density contrast of jet to ambient medium, or the external sonic Mach number of the jet.
The mechanism we suggest should work for a variety of jet applications, e.g. protostellar or extragalactic jets, and internal jet shocks (jet knots) or external shocks between the jet and ambient gas (entrainment). For typical parameter values for protostellar jets, the numerically derived rotation feature looks consistent with the observations, i.e. rotational velocities of 0.1-1% of the jet bulk velocity.

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Galactic H_2CO Densitometry I: Pilot Survey of Ultracompact HII Regions and Methodology

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We present a pilot survey of 21 lines of sight towards ultracompact HII (UCHII) regions and three towards continuum-free lines of sight in the formaldehyde (H_2CO) $1_{10} - 1_{11}$ (6 cm) and $2_{11} - 2_{12}$ (2 cm) transitions, using the H_2CO centimeter lines as a molecular gas densitometer. Using Arecibo and Green Bank beam-matched observations, we measure the density of 51 detected H_2CO line pairs and present upper limits on density for an additional 24 detected $1_{10}-1_{11}$ lines. We analyze the systematic uncertainties in the H_2CO densitometer, achieving H_2 density measurements with accuracies $\sim 0.1-0.3$ dex. The densities measured are not correlated with distance, implying that it is possible to make accurate density measurements throughout the galaxy without a distance bias. We confirm that ultracompact HII regions are associated with, and possibly embedded in, gas at densities $n(H_2) \gtrsim 10^5$ cm^{-3}. The densities measured in line-of-sight molecular clouds suggest that they consist of low volume filling factor ($f \sim 10^{-2}$) gas at high ($n(H_2) > 10^4$ cm^{-3}) density, which is inconsistent with purely supersonic turbulence and requires high-density clumping greater than typically observed in gravo-turbulent simulations. We observe complex line morphologies that indicate density variations with velocity around UCHII regions, and we classify a subset of the UCHII molecular envelopes as collapsing or expanding. We compare these measurements to Bolocam Galactic Plane Survey 1.1 mm observations, and note that most UCHII regions have 1.1 mm emission consisting of significant (5-70%) free-free emission and are therefore not necessarily dominated by optically thin dust emission as is often assumed when computing clump masses. A comparison of our data with the Mangum et al. 2008 starburst sample shows that the area filling factor of dense ($n(H_2) \sim 10^5$ cm^{-3}) molecular gas in typical starburst galaxies is $\lesssim 0.01$, but in extreme starburst galaxies like Arp 220, is ~ 0.1, suggesting that Arp 220 is physically similar to an oversized UCHII region.

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JCMT HARP CO 3-2 Observations of Molecular Outflows in W5

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New JCMT HARP CO 3-2 observations of the W5 star forming complex are presented, totaling an area of ~ 12000 arcmin^2 with sensitivity better than 0.1 K per 0.4 km s^{-1} channel. We discovered 55 CO outflow candidates, of which 40 are associated with W5 and 15 are more distant than the Perseus arm. Most of the outflows are located on the periphery of the W5 HII region. However, two outflow clusters are > 5 pc from the ionization fronts, indicating that their driving protostars formed without directly being triggered by the O-stars in W5. We compare the derived outflow

properties to those in Perseus and find that the total W5 outflow mass is surprisingly low given the cloud masses. The outflow mass deficiency in the more massive W5 cloud ($M(\mathrm{H}_2) \sim 5\times10^4 M\_odot$) can be explained if ionizing radiation dissociates molecules as they break out of their host cloud cores. Although CO J=3-2 is a good outflow tracer, it is likely to be a poor mass tracer because of sub-thermal line excitation and high opacity, which may also contribute to the outflow mass discrepancy. It is unlikely that outflows could provide the observed turbulent energy in the W5 molecular clouds even accounting for undetected outflow material. Many cometary globules have been observed with velocity gradients from head to tail, displaying strong interaction with the W5 HII region and exhibiting signs of triggered or revealed star formation in their heads. Because it is observed face-on, W5 is an excellent region to study feedback effects, both positive and negative, of massive stars on star formation.

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The Global Evolution of Giant Molecular Clouds II: The Role of Accretion

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We present virial models for the global evolution of giant molecular clouds. Focusing on the presence of an accretion flow, and accounting for the amount of mass, momentum, and energy supplied by accretion and star formation feedback, we are able to follow the growth, evolution, and dispersal of individual giant molecular clouds. Our model clouds reproduce the scaling relations observed in both galactic and extragalactic clouds. We find that accretion and star formation contribute roughly equal amounts of turbulent kinetic energy over the lifetime of the cloud. Clouds attain virial equilibrium and grow in such a way as to maintain roughly constant surface densities, with typical surface densities of order $50-200$ $\mathrm{M}_\odot$ pc^{-2}, in good agreement with observations of giant molecular clouds in the Milky Way and nearby external galaxies. We find that as clouds grow, their velocity dispersion and radius must also increase, implying that the linewidth-size relation constitutes an age sequence. Lastly, we compare our models to observations of giant molecular clouds and associated young star clusters in the LMC and find good agreement between our model clouds and the observed relationship between H II regions, young star clusters, and giant molecular clouds.

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Accretion, jets and winds: High-energy emission from young stellar objects

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This article summarizes the processes of high-energy emission in young stellar objects. Stars of spectral type A and B are called Herbig Ae/Be (HAeBe) stars in this stage, all later spectral types are termed classical T Tauri stars (CTTS). Both types are studied by high-resolution X-ray and UV spectroscopy and modeling. Three mechanisms contribute to the high-energy emission from CTTS: 1) CTTS have active coronae similar to main-sequence stars, 2) the accreted material passes through an accretion shock at the stellar surface, which heats it to a few MK, and 3) some CTTS drive powerful outflows. Shocks within these jets can heat the plasma to X-ray emitting temperatures. Coronae are already well characterized in the literature; for the latter two scenarios models are shown. The magnetic field suppresses motion perpendicular to the field lines in the accretion shock, thus justifying a 1D geometry. The radiative loss is calculated as optically thin emission. A mixture of shocked and coronal gas is fitted to X-ray observations of accreting CTTS. Specifically, the model explains the peculiar line-ratios in the He-like triplets of Ne IX and O VII. All stars require only small mass accretion rates to power the X-ray emission. In contrast, the HAeBe HD 163296 has line ratios similar to coronal sources, indicating that neither a high density nor a strong UV-field is present in the region

of the X-ray emission. This could be caused by a shock in its jet. Similar emission is found in the deeply absorbed CTTS DG Tau. Shock velocities between 400 and 500 km/s are required to explain the observed spectrum.

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Mapping Large-Scale CO Depletion in a Filamentary Infrared Dark Cloud

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Infrared Dark Clouds (IRDCs) are cold, high mass surface density and high density structures, likely to be representative of the initial conditions for massive star and star cluster formation. CO emission from IRDCs has the potential to be useful for tracing their dynamics, but may be affected by depleted gas phase abundances due to freeze-out onto dust grains. Here we analyze $C^{18}O$ $J = 1 \rightarrow 0$ and $J = 2 \rightarrow 1$ emission line data, taken with the IRAM 30m telescope, of the highly filamentary IRDC G035.39.-0033. We derive the excitation temperature as a function of position and velocity, with typical values of ~ 7 K, and thus derive total mass surface densities, $\Sigma_{\rm C18O}$, assuming standard gas phase abundances and accounting for optical depth in the line, which can reach values of ~ 1. The mass surface densities reach values of $\sim 0.07\,{\rm g\,cm^{-2}}$. We compare these results to the mass surface densities derived from mid-infrared (MIR) extinction mapping, $\Sigma_{\rm SMF}$, by Butler & Tan, which are expected to be insensitive to the dust temperatures in the cloud. With a significance of $< 10\sigma$, we find $\Sigma_{\rm C18O}/\Sigma_{\rm SMF}$ decreases by about a factor of 5 as Σ increases from ~ 0.02 to $\sim 0.2\,{\rm g\,cm^{-2}}$, which we interpret as evidence for CO depletion. Several hundred solar masses are being affected, making this one of the most massive clouds in which CO depletion has been observed directly. We present a map of the depletion factor in the filament and discuss implications for the formation of the IRDC.

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On the Reliability of Stellar Ages and Age Spreads Inferred from Pre-Main Sequence Evolutionary Models

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We revisit the problem of low-mass pre-main-sequence (PMS) stellar evolution and its observational consequences for where stars fall on the Hertzsprung-Russell diagram (HRD). In contrast to most previous work, our models follow stars as they grow from small masses via accretion, and we perform a systematic study of how the stars' HRD evolution is influenced by their initial radius, by the radiative properties of the accretion flow, and by the accretion history, using both simple idealized accretion histories and histories taken from numerical simulations of star cluster formation. We compare our numerical results to both non-accreting isochrones and to the positions of observed stars in the HRD, with a goal of determining whether both the absolute ages and the age dispersions inferred from non-accreting isochrones are reliable. We show that non-accreting isochrones can sometimes overestimate stellar ages for more massive stars (those with effective temperatures above ~ 3500 K), thereby explaining why non-accreting isochrones often suggest a systematic age difference between more and less massive stars in the same cluster. However, we also find the only way to produce a similar overestimate for the ages of cooler stars is if these stars grow from $\sim 0.01\ M_\odot$ seed protostars

that are an order of magnitude smaller than predicted by current theoretical models, and if the size of the seed protostar correlates systematically with the final stellar mass at the end of accretion. We therefore conclude that, unless both of these conditions are met, inferred ages and age spreads for cool stars are reliable, at least to the extent that the observed bolometric luminosities and temperatures are accurate. Finally, we note that the time-dependence of the mass accretion rate has remarkably little effect on low-mass stars' evolution on the HRD, and that such time dependence may be neglected for all stars except those with effective temperatures above ~ 4000 K.

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Gravitational Fragmentation of Expanding Shells. I. Linear Analysis

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We perform a linear perturbation analysis of expanding shells driven by expansions of H*II* regions. The ambient gas is assumed to be uniform. As an unperturbed state, we develop a semi-analytic method for deriving the time evolution of the density profile across the thickness. It is found that the time evolution of the density profile can be divided into three evolutionary phases, deceleration-dominated, intermediate, and self-gravity-dominated phases. The density peak moves relatively from the shock front to the contact discontinuity as the shell expands. We perform a linear analysis taking into account the asymmetric density profile obtained by the semi-analytic method, and imposing the boundary conditions for the shock front and the contact discontinuity while the evolutionary effect of the shell is neglected. It is found that the growth rate is enhanced compared with the previous studies based on the thin-shell approximation. This is due to the boundary effect of the contact discontinuity and asymmetric density profile that were not taken into account in previous works.

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Gravitational Fragmentation of Expanding Shells. II. Three-dimensional Simulations

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We investigate the gravitational fragmentation of expanding shells driven by H II regions using the three-dimensional Lagrangian simulation codes based on the Riemann solver, called Godunov smoothed particle hydrodynamics. The ambient gas is assumed to be uniform. In order to attain high resolution to resolve the geometrically thin dense shell, we calculate not the whole but a part of the shell. We find that perturbations begin to grow earlier than predicted by linear analysis under the thin-shell approximation. The wavenumber of the most unstable mode is larger than that in the thin-shell linear analysis. The development of the gravitational instability is accompanied by the significant deformation of the contact discontinuity. These results are consistent with a linear analysis presented by Iwasaki et al. that have taken into account the density profile across the thickness and approximate shock and contact discontinuity boundary conditions. We derive useful analytic formulae for the fragment scale and the epoch when the gravitational instability begins to grow.

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Stirring up the dust: A dynamical model for halo-like dust clouds in transitional disks

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A small number of young stellar objects show signs of a halo-like structure of optically thin dust. This halo or torus is located within a few AU of the star, but its origin has not yet been understood. A dynamically excited cloud of planetesimals colliding to eventually form dust could produce such a structure. The cause of the dynamical excitation could be one or more planets. This work investigates an inwardly migrating planet that is dynamically scattering planetesimals as a possible cause for the observed structures. If this mechanism is responsible, the observed halo-like structure could be used to infer the existence of planets in these systems. We present analytical estimates on the maximum inclination reached owing to dynamical interactions between planetesimals and a migrating planet. A symplectic integrator is used to simulate the effect of a migrating planet on a population of planetesimals. It is found that an inwardly migrating planet is only able to scatter the material it encounters to highly-inclined orbits if the material is on an eccentric orbit. Such eccentric orbits can be the result of resonance trapping and eccentricity pumping. Simulations show that for a certain range of migration rates and planet masses, resonance capture combined with planetary migration indeed causes the planetesimals to reach eccentric orbits and subsequently get scattered to highly-inclined orbits. The size distribution of the resulting dust is calculated determined to find the total mass and optical depth, which are found to compare reasonably well with the observed structures. Dynamical scattering of planetesimals caused by a planet migrating in, followed by the grinding down of these planetesimals to dust grains, appears to be a promising explanation for the inferred circumstellar dust clouds. Further study is needed to see if the haloes can be used to infer the presence of planets.

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Multidimensional models of hydrogen and helium emission line profiles for classical T Tauri Stars: method, tests and examples

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We present multidimensional non-LTE radiative transfer models of hydrogen and helium line profiles formed in the accretion flows and the outflows near the star-disk interaction regions of classical T Tauri stars (CTTSs). The statistical equilibrium calculations, performed under the assumption of the Sobolev approximation using the radiative transfer code TORUS, has been improved to include HeI and HeII energy levels. This allows us to probe the physical conditions of the inner wind of CTTSs by simultaneously modelling the robust wind diagnostic line HeI λ10830 and the accretion diagnostic lines such as Paβ, Brγ and HeI λ5876. The code has been tested in one and two dimensional problems, and we have shown that the results are in agreement with established codes. We apply the model to the complex flow geometries of CTTSs. Example model profiles are computed using the combinations of (1) magnetospheric accretion and disc wind, and (2) magnetospheric accretion and the stellar wind. In both cases, the model produces line profiles which are qualitatively similar to those found in observations. Our models are consistent with the scenario in which the narrow blueshifted absorption component of HeI λ10830 seen in observations is caused by a disc wind, and the wider blueshifted absorption component (the P-Cygni profile) is caused by a bipolar stellar wind. However, we do not have a strong constraint on the relative importance of the wind and the magnetosphere for the 'emission' component. Our preliminary calculations suggest that the temperature of the disc wind and stellar winds cannot be much higher than ∼10,000 K, on the basis of the strengths of hydrogen lines. Similarly the temperature of the magnetospheric accretion cannot be much higher than ∼10,000 K. With these low temperatures, we find that the photoionzation by high energy photons (e.g. X-rays) is necessary to produce HeI λ10830 in emission and to produce the blueshifted

absorption components.

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Are the Outflows in FU Orionis Systems Driven by the Stellar Magnetic Field?

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FU Orionis (FUOR) outbursts are major optical brightening episodes in low-mass protostars that evidently correspond to rapid mass-accretion events in the innermost region of a protostellar disk. The outbursts are accompanied by strong outflows, with the inferred mass outflow rates reaching $\sim 10\%$ of the mass inflow rates. Shu et al. proposed that the outflows represent accreted disk material that is driven centrifugally from the spun-up surface layers of the protostar by the stellar magnetic field. This model was critiqued by Calvet et al., who argued that it cannot reproduce the photospheric absorption-line shifts observed in the prototype object FU Ori. Calvet et al. proposed that the wind is launched, instead, from the surface of the disk on scales of a few stellar radii by a nonstellar magnetic field. In this paper we present results from numerical simulations of disk accretion onto a slowly rotating star with an aligned magnetic dipole moment that gives rise to a kilogauss-strength surface field. We demonstrate that, for parameters appropriate to FU Ori, such a system can develop a strong, collimated disk outflow of the type previously identified by Romanova et al. in simulations of protostars with low and moderate accretion rates. At the high accretion rate that characterizes the FUOR outburst phase, the radius $r_{\rm m}$ at which the disk is truncated by the stellar magnetic field moves much closer to the stellar surface, but the basic properties of the outflow, which is launched from the vicinity of $r_{\rm m}$ along opened-up stellar magnetic field lines, remain the same. These properties are distinct from those of the X-celerator (or the closely related X-wind) mechanism proposed by Shu et al. – in particular, the outflow is driven from the start by the magnetic pressure-gradient force, not centrifugally, and it is more strongly collimated. We show that the simulated outflow can in principle account for the main observed characteristics of FUOR winds, including the photospheric line shifts measured in FU Ori. A detailed radiative-transfer calculation is, however, required to confirm the latter result.

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Spectral Energy Distributions of Young Stars in IC 348: The Role of Disks in Angular Momentum Evolution of Young, Low-Mass Stars

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Theoretical work suggests that a young star's angular momentum content and rotation rate may be strongly influenced by magnetic interactions with its circumstellar disk. A generic prediction of these 'disk-locking' theories is that a disk-locked star will be forced to co-rotate with the Keplerian angular velocity of the inner edge of the disk; that is, the disk's inner truncation radius should equal its co-rotation radius. These theories have also been interpreted to suggest a gross correlation between young stars' rotation periods and the structural properties of their circumstellar disks, such that slowly rotating stars possess close-in disks that enforce the star's slow rotation, whereas rapidly rotating stars possess anemic or evacuated inner disks that are unable to brake the stars and instead the stars spin up as they contract. To test these expectations, we model the spectral energy distributions of 33 young stars in IC 348 with known rotation periods and infrared excesses indicating the presence of circumstellar disks. For each star, we match

the observed spectral energy distribution, typically sampling 0.6 - 8.0 microns, to a grid of 200,000 pre-computed star+disk radiative transfer models, from which we infer the disk's inner-truncation radius. We then compare this truncation radius to the disk's co-rotation radius, calculated from the star's measured rotation period. We do not find obvious differences in the disk truncation radii of slow rotators vs. rapid rotators. This holds true both at the level of whether close-in disk material is present at all, and in analyzing the precise location of the inner disk edge relative to the co-rotation radius amongst the subset of stars with close-in disk material. One interpretation is that disk-locking is unimportant for the IC 348 stars in our sample. Alternatively, if disk-locking does operate, then it must operate on both the slow and rapid rotators, potentially producing both spin-up and spin-down torques, and the transition from the disk-locked state to the disk-released state must occur more rapidly than the stellar contraction timescale.

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Nonideal MHD Effects and Magnetic Braking Catastrophe in Protostellar Disk Formation

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Dense, star-forming, cores of molecular clouds are observed to be significantly magnetized. A realistic magnetic field of moderate strength has been shown to suppress, through catastrophic magnetic braking, the formation of a rotationally supported disk during the protostellar accretion phase of low-mass star formation in the ideal MHD limit. We address, through 2D (axisymmetric) simulations, the question of whether realistic levels of nonideal effects, computed with a simplified chemical network including dust grains, can weaken the magnetic braking enough to enable a rotationally supported disk to form. We find that ambipolar diffusion, the dominant nonideal MHD effect over most of the density range relevant to disk formation, does not enable disk formation, at least in 2D. The reason is that ambipolar diffusion allows the magnetic flux that would be dragged into the central stellar object in the ideal MHD limit to pile up instead in a small circumstellar region, where the magnetic field strength (and thus the braking efficiency) is greatly enhanced. We also find that, on the scale of tens of AU or more, a realistic level of Ohmic dissipation does not weaken the magnetic braking enough for a rotationally supported disk to form, either by itself or in combination with ambipolar diffusion. The Hall effect, the least explored of these three nonideal MHD effects, can spin up the material close to the central object to a significant, supersonic rotation speed, even when the core is initially non-rotating, although the spun-up material remains too sub-Keplerian to form a rotationally supported disk. The problem of catastrophic magnetic braking that prevents disk formation in dense cores magnetized to realistic levels remains unresolved. Possible resolutions of this problem are discussed.

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Revealing the "missing" low-mass stars in the S254-S258 star forming region by deep X-ray imaging

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Context: X-ray observations provide a very good way to reveal the population of young stars in star forming regions avoiding the biases introduced when selecting samples based on infrared excess.
Aims: The aim of this study was to find an explanation for the remarkable morphology of the central part of the

S254–S258 star forming complex, where a dense embedded cluster of very young stellar objects (S255-IR) is sandwiched between the two HII regions S255 and S257. This interesting configuration had led to different speculations such as dynamical ejection of the B-stars from the central cluster or triggered star formation in a cloud that was swept up in the collision zone between the two expanding HII regions. The presence or absence, and the spatial distribution of low-mass stars associated with these B-stars can discriminate between the possible scenarios.
Methods: We performed a deep *Chandra* X-ray observation of the S254–S258 region in order to efficiently discriminate young stars (with and without circumstellar matter) from the numerous older field stars in the area.
Results: We detected 364 X-ray point sources in a $17' \times 17'$ field ($\approx 8 \times 8$ pc). This X-ray catalog provides, for the first time, a complete sample of all young stars in the region down to $\sim 0.5\,M_{\odot}$. A clustering analysis identifies three significant clusters: the central embedded cluster S255-IR and two smaller clusterings in S256 and S258. Sixty-four X-ray sources can be classified as members in one of these clusters. After accounting for X-ray background contaminants, this implies that about 250 X-ray sources constitute a widely scattered population of young stars, distributed over the full field-of-view of our X-ray image. This distributed young stellar population is considerably larger than the previously known number of non-clustered young stars selected by infrared excesses. Comparison of the X-ray luminosity function with that of the Orion Nebula Cluster suggests a total population of $\sim$ 2000 young stars in the observed part of the S254-S258 region.
Conclusions: The observed number of $\sim$ 250 X-ray detected distributed young stars agrees well with the expectation for the low-mass population associated to the B-stars in S255 and S257 as predicted by an IMF extrapolation. These results are consistent with the scenario that these two B-stars represent an earlier stellar population and that their expanding HII regions have swept up the central cloud and trigger star formation (i.e. the central embedded cluster S255-IR) therein.

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Low abundance, strong features: Window-dressing crystalline forsterite in the disk wall of HD 100546

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Forsterite is one of the crystalline dust species that is often observed in protoplanetary disks and solar system comets. Being absent in the interstellar medium, it must be produced during the disk lifetime. It can therefore serve as a tracer of dust processing and disk evolution, which can lead to a better understanding of the physical processes occurring in the disk, and possibly planet formation. However, the connection of these processes with the overall disk crystallinity remains unclear. We aim to characterize the forsterite abundance and spatial distribution in the disk of the Herbig Be star HD 100546, to investigate if a connection exists with the large disk gap. We use a 2D radiative transfer code, MCMax, to model the circumstellar dust around HD 100546. We use VISIR Q-band imaging to probe the outer disk geometry and mid-infrared features to model the spatial distribution of forsterite. The temperature-dependent shape of the 69 micron feature observed with Herschel PACS is used as a critical tool to constrain this distribution. We find a crystalline mass fraction of 40 - 60 %, located close to the disk wall between 13 and 20 AU, and possibly farther out at the disk surface. The forsterite is in thermal contact with the other dust species. We put an upper limit on the iron content of forsterite of 0.3 %. Optical depth effects play a key role in explaining the observed forsterite features, hiding warm forsterite from view at short wavelengths. The disk wall acts as a showcase: it displays a localized high abundance of forsterite, which gives rise to a high observed crystallinity, while the overall mass fraction of forsterite is a factor of ten lower.

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Star Formation Activity in the Galactic HII Complex S255-S257

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We present results on the star-formation activity of an optically obscured region containing an embedded cluster (S255-IR) and molecular gas between two evolved HII regions S255 and S257. We have studied the complex using optical, near-infrared (NIR) imaging, optical spectroscopy and radio continnum mapping at 15 GHz, along with Spitzer-IRAC results. It is found that the main exciting sources of the evolved HII regions S255 and S257 and the compact HII regions associated with S255-IR are of O9.5 - B3 V nature, consistent with previous observations. Our NIR observations reveal 109 likely young stellar object (YSO) candidates in an area of $\sim$ 4'.9 x 4'.9 centered on S255-IR, which include 69 new YSO candidates. Our observations increased the number of previously identified YSOs in this region by 32%. To see the global star formation, we constructed the V-I/V diagram for 51 optically identified IRAC YSOs in an area of $\sim$ 13' x 13' centered on S255-IR. We suggest that these YSOs have an approximate age between 0.1 - 4 Myr, indicating a non-coeval star formation. Using spectral energy distribution models, we constrained physical properties and evolutionary status of 31 and 16 YSO candidates outside and inside the gas ridge, respectively. The models suggest that the sources associated within the gas ridge are of younger population (mean age $\sim$ 1.2 Myr) than the sources outside the gas ridge (mean age $\sim$ 2.5 Myr). The positions of the young sources inside the gas ridge at the interface of the HII regions S255 and S257, favor a site of induced star formation.

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Volume Density Thresholds for Overall Star Formation imply Mass-Size Thresholds for Massive Star Formation

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We aim at understanding the massive star formation (MSF) limit $m(r) = 870 M_{\odot} (r/pc)^{1.33}$ in the mass-size space of molecular structures recently proposed by Kauffmann & Pillai (2010). As a first step, we build on the hypothesis of a volume density threshold for overall star formation and the model of Parmentier (2011) to establish the mass-radius relations of molecular clumps containing given masses of star-forming gas. Specifically, we relate the mass m_{clump},

radius r_{clump} and density profile slope $-p$ of molecular clumps which contain a mass m_{th} of gas denser than a volume density threshold ρ_{th}. In a second step, we use the relation between the mass of embedded-clusters and the mass of their most-massive star to estimate the minimum mass of star-forming gas needed to form a $10\,M_\odot$ star. Assuming a star formation efficiency of $SFE \simeq 0.30$, this gives $m_{th,crit} \simeq 150 M_\odot$. In a third step, we demonstrate that, for sensible choices of the clump density index ($p \simeq 1.7$) and of the cluster formation density threshold ($n_{th} \simeq 10^4\,cm^{-3}$), the line of constant $m_{th,crit} \simeq 150 M_\odot$ in the mass-radius space of molecular structures equates with the MSF limit for spatial scales larger than 0.3 pc. Hence, the observationally inferred MSF limit of Kauffmann & Pillai is consistent with a threshold in star-forming gas mass beyond which the star-forming gas reservoir is large enough to allow the formation of massive stars. For radii smaller than 0.3 pc, the MSF limit is shown to be consistent with the formation of a $10\,M_\odot$ star out of its individual pre-stellar core of density threshold $n_{th} \simeq 10^5\,cm^{-3}$. The inferred density thresholds for the formation of star clusters and individual stars within star clusters match those previously suggested in the literature.

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VLT/NACO Polarimetric Differential Imaging of HD100546 - Disk Structure and Dust Grain Properties between 10-140 AU

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We present polarimetric differential imaging (PDI) data of the circumstellar disk around the Herbig Ae/Be star HD100546 obtained with VLT/NACO. We resolve the disk in polarized light in the H and K_s filter between ∼0.1–1.4″ (i.e., ∼10–140 AU). The innermost disk regions are directly imaged for the first time and the mean apparent disk inclination and position angle are derived. The surface brightness along the disk major axis drops off roughly with $S(r) \propto r^{-3}$ but has a maximum around 0.15″ suggesting a marginal detection of the main disk inner rim at ∼15 AU. We find a significant brightness asymmetry along the disk minor axis in both filters with the far side of the disk appearing brighter than the near side. This enhanced backward scattering and a low total polarization degree of the scattered disk flux of 14^{+19}_{-8}% suggests that the dust grains on the disk surface are larger than typical ISM grains. Empirical scattering functions reveal the backward scattering peak at the largest scattering angles and a second maximum for the smallest scattering angles. This indicates a second dust grain population preferably forward scattering and smaller in size. It shows that, relatively, in the inner disk regions (40–50 AU) a higher fraction of larger grains is found compared to the outer disk regions (100–110 AU). Finally, our images reveal distinct substructures between 25–35 AU physical separation from the star and we discuss the possible origin for the two features in the context of ongoing planet formation.

Accepted by ApJ

http://xxx.lanl.gov/abs/1106.1101

Very Large Array Observations of Ammonia in Infrared-Dark Clouds I: Column Density and Temperature Structure

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We present Very Large Array observations of NH_3 (1,1) and (2,2) in a sample of six infrared-dark clouds (IRDCs) with distances from 2 to 5 kpc. We find that ammonia serves as an excellent tracer of dense gas in IRDCs, showing no evidence of depletion, and the average abundance in these clouds is 8.1×10^{-7}. Our sample consists of four IRDCs with 24 μm embedded protostars and two that appear starless. We calculate the kinetic temperature of the gas in IRDCs and find no significant difference between starless and star-forming IRDCs. We find that the bulk of the gas is between 8 and 13 K, indicating that any embedded or nearby stars or clusters do not affect the gas temperature dramatically. Though IRDCs have temperatures and volume densities on par with local star formation regions of lower mass, they consist of much more mass which induces very high internal pressures. In order for IRDCs to survive as coherent structures, the internal pressure must be balanced by a confining pressure provided by the high concentration of molecular clouds in the spiral arm in which they reside. The high molecular concentration and pressure is roughly consistent with gas dynamics of a bar galaxy.

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Binary Formation Mechanisms: Constraints from the Companion Mass Ratio Distribution

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We present a statistical comparison of the mass ratio distribution of companions, as observed in different multiplicity surveys, to the most recent estimate of the single object mass function (Bochanski et al. 2010). The main goal of our analysis is to test whether or not the observed companion mass ratio distribution (CMRD) as a function of primary star mass and star formation environment is consistent with having been drawn from the field star IMF. We consider samples of companions for M dwarfs, solar type and intermediate mass stars, both in the field as well as clusters or associations, and compare them with populations of binaries generated by random pairing from the assumed IMF for a fixed primary mass. With regard to the field we can reject the hypothesis that the CMRD was drawn from the IMF for different primary mass ranges: the observed CMRDs show a larger number of equal-mass systems than predicted by the IMF. This is in agreement with fragmentation theories of binary formation. For the open clusters α Persei and the Pleiades we also reject the IMF random-pairing hypothesis. Concerning young star-forming regions, currently we can rule out a connection between the CMRD and the field IMF in Taurus but not in Chamaeleon I. Larger and different samples are needed to better constrain the result as a function of the environment. We also consider other companion mass functions (CMF) and we compare them with observations. Moreover the CMRD both in the field and clusters or associations appears to be independent of separation in the range covered by the observations. Combining therefore the CMRDs of M (1-2400 AU) and G (28-1590 AU) primaries in the field and intermediate mass primary binaries in Sco OB2 (29-1612 AU) for mass ratios, $q = M_2/M_1$, from 0.2 to 1, we find that the best chi-square fit follows a power law $dN/dq \propto q^{\beta}$, with $\beta = -0.50 \pm 0.29$, consistent with previous results. Finally we note that the KS test gives a $\sim$1% probability of the observed CMRD in the Pleiades and Taurus being consistent with that observed for solar type primaries in the field over comparable primary mass range. This highlights the value of using CMRDs to understand which star formation events contribute most to the field.

Accepted by The Astrophysical Journal

http://arxiv.org/abs/1106.3064

The mm-colors of a young binary disk system in the Orion Nebula Cluster

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We present new EVLA continuum observations at 7 mm of the 253-1536 binary disk system in the Orion Nebula

Cluster. The measured fluxes were combined with data in the sub-mm to derive the millimeter spectral index of each individual disk component. We show how these observations can be used to test the models of dust evolution and early growth of solids in protoplanetary disks. Our analysis indicates that the disk with lower density and higher temperature hosts larger grains than the companion disk. This result is the opposite of what predicted by the dust evolution models. The models and observational results can be reconciled if the viscosity α-parameter differs by more than a factor of ten in the two disks, or if the distribution of solids in the disks is strongly affected by radial motions. This analysis can be applied to future high-angular resolution observations of young disks with EVLA and ALMA to provide even stronger observational constraints to the models of dust evolution in protoplanetary disks.

Accepted by ApJ Letters Special Issue on early EVLA results

http://arxiv.org/abs/1106.2150

Chandra Evidence for Extended X-ray Structure in RY Tau

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We report results of a sensitive *Chandra* ACIS-S observation of the classical T Tauri star RY Tau. Previous studies have shown that it drives a spectacular bipolar jet whose blueshifted component is traced optically along P.A. $\approx 295^\circ$ at separations of $1.''5$ - $31''$ from the star. Complex X-ray emission is revealed, including a very soft non-variable spectral component (some of which may originate in shocks), a superhot flaring component (T $\gtrsim$ 100 MK), and faint extended structure near the star. The structure is visible in deconvolved images and extends northwestward out to a separation of $1.''7$, overlapping the inner part of the optical jet. Image analysis suggests that most of the extension is real, but some contamination by PSF-induced structure within the central arcsecond may be present. The predicted temperature for a shock-heated jet based on jet speed and shock speed estimates from optical measurements is too low to explain the extended X-ray structure. Either higher speed material within the jet has escaped optical detection or other mechanisms besides shock-heating are involved. Alternative mechanisms that could produce higher temperature plasma at small offsets to the northwest of RY Tau include magnetic heating in the jet, hot plasmoids ejected at high speeds, or X-ray emission from a putative close companion whose presence has been inferred from *Hipparcos* variations.

Accepted by ApJ

Preprints: http://arxiv.org/abs/1105.5125

CH abundance gradient in TMC-1

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The aim of this study is to examine if the well-known chemical gradient in TMC-1 is reflected in the amount of rudimentary forms of carbon available in the gas-phase. As a tracer we use the CH radical which is supposed to be well correlated with carbon atoms and simple hydrocarbon ions. We observed the 9-cm Λ-doubling lines of CH

along the dense filament of TMC-1. The CH column densities were compared with the total H_2 column densities derived using the 2MASS NIR data and previously published SCUBA maps and with OH column densities derived using previous observations with Effelsberg. We also modelled the chemical evolution of TMC-1 adopting physical conditions typical of dark clouds using the UMIST Database for Astrochemistry gas-phase reaction network to aid the interpretation of the observed OH/CH abundance ratios. The CH column density has a clear peak in the vicinity of the cyanopolyyne maximum of TMC-1. The fractional CH abundance relative to H_2 increases steadily from the northwestern end of the filament where it lies around $1.0\,10^{-8}$, to the southeast where it reaches a value of $2.0\,10^{-8}$. The OH and CH column densities are well correlated, and we obtained OH/CH abundance ratios of $\sim 16 - 20$. These values are clearly larger than what has been measured recently in diffuse interstellar gas and is likely to be related to C to CO conversion at higher densities. The good correlation between CH and OH can be explained by similar production and destruction pathways. We suggest that the observed CH and OH abundance gradients are mainly due to enhanced abundances in a low-density envelope which becomes more prominent in the southeastern part and seems to continue beyond the dense filament. An extensive envelope probably signifies an early stage of dynamical evolution, and conforms with the detection of a large CH abundance in the southeastern part of the cloud. The implied presence of other simple forms of carbon in the gas phase provides a natural explanation for the observation of "early-type" molecules in this region.

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http://arxiv.org/abs/1105.5920

Periodic variability of 6.7 GHz methanol masers in G22.357+0.066

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We report the discovery of periodic flares of 6.7 GHz methanol maser in the young massive stellar object G22.357+0.066. The target was monitored in the methanol maser line over 20 months with the Torun 32 m telescope. The emission was also mapped at two epochs using the EVN. The 6.7 GHz methanol maser shows periodic variations with a period of ∼179 days. The periodic behavior is stable for the last three densely sampled cycles and has even been stable over ∼12 years, as the archival data suggest. The maser structure mapped with the EVN remains unchanged at two epochs just at the putative flare maxima separated by two years. The time delays of up to ∼16 days seen between maser features are combined with the map of spots to construct the 3-dimensional structure of the maser region. The emission originating in a single ∼100 AU layer can be modulated by periodic changes in the infrared pumping radiation or in the free-free background emission from an HII region.

Accepted by Astronomy & Astrophysics Letters (531, L3)

http://arxiv.org/abs/1105.4089

Imaging studies of NGC 3372, the Carina Nebula – III. The properties of G287.47-0.54 (Tr 14-N4), an embedded young cluster and its associated H_2 emission

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New deep broad- and narrow-band (JHK and Br γ at 2.17 μm and H_2 at 2.12 μm) near-infrared images of the mid-infrared source G287.47-0.54 (Tr14-N4) taken with the Baade Magellan telescope are presented and analysed along with archive 3.6 to 8 μm *Spitzer* images. The analysis of these data demonstrates the presence of a compact ($r \sim 23$ *arcsec*, 0.3 pc), embedded infrared cluster with at least 72 young members. The colour-magnitude diagram of

the cluster suggests an age of approximately 10^5 years, consistent with the large fraction ($\geq 32\%$) of embedded sources found to show significant excess emission at $\lambda > 2\,\mu$m. The two youngest and most luminous sources are located close to the cluster nucleus. The properties of their spectral energy distributions (SEDs) indicate that these are Class I young stellar objects (YSOs) with masses in the range $7-9\ M_\odot$ and luminosities between $400-800\ L_\odot$. We derive the presence of a tilted ($i \sim 40-70°$) disk of size ≥ 0.05 pc around one of these YSOs, #902. This object is seen directly through the dust disk only at $\lambda \geq 2.2$, with most of the observed near-IR radiation being scattered light from lobes on both sides of the disk. In contrast, the second bright YSO, #438, is seen directly even in the near-infrared and also shows symmetrically elongated features that seem to be caused by scattering. The young cluster G287.47-0.54, is embedded at the head of a dust pillar and is another example of a photodissociation region (PDR) where triggered star formation occurs as a consequence of the interaction of a very massive developed cluster, in this case Tr 16, with a dense molecular core. It appears that the dense cloudlet is sticking out of the remnant giant molecular cloud located at the far side of the northern Carina nebula. Five small molecular hydrogen emission knots at $2.12\,\mu$m with no Brγ counterpart are found in the vicinity of a CO peak, some 0.4 pc northwest of the cluster nucleus. Most probably, these are shock excited, suggesting the presence of mass outflows in the region. At present, it is unclear whether the engine of this outflow is a member of the cluster or rather it is an, undetected, younger YSO deeply embedded in the molecular core.

Accepted by MNRAS

First hyperfine resolved far-infrared OH spectrum from a star-forming region

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OH is an important molecule in the H_2O chemistry and the cooling budget of star-forming regions. The goal of the *Herschel* key program 'Water in Star-forming regions with *Herschel*' (WISH) is to study H_2O and related species during protostellar evolution. Our aim in this letter is to assess the origin of the OH emission from star-forming regions and constrain the properties of the emitting gas. High-resolution observations of the OH $^2\Pi_{1/2}\ J = 3/2-1/2$ triplet at 1837.8 GHz (163.1 μm) towards the high-mass star-forming region W3 IRS 5 with the Heterodyne Instrument for the Far-Infrared (HIFI) on *Herschel* reveal the first hyperfine velocity-resolved OH far-infrared spectrum of a star-forming region. The line profile of the OH emission shows two components: a narrow component (FWHM $\approx 4-5$ km s^{-1}) with partially resolved hyperfine structure resides on top of a broad (FWHM ≈ 30 km s^{-1}) component. The narrow emission agrees well with results from radiative transfer calculations of a spherical envelope model for W3 IRS 5 with a constant OH abundance of $x_{\rm OH} \approx 8 \times 10^{-9}$. Comparison with H_2O yields OH/H_2O abundance ratios of around 10^{-3} for $T > 100$ K and around unity for $T < 100$ K, consistent with the current picture of the dense cloud chemistry with freeze-out and photodesorption. The broad component is attributed to outflow emission. An abundance ratio of OH/$H_2O > 0.028$ in the outflow is derived from comparison with results of water line modeling. This ratio can be explained by a fast J-type shock or a slower UV-irradiated C-type shock.

Accepted by Astronomy & Astrophysics as a letter

http://arxiv.org/abs/1105.5026

Observational study of the formation of sub-stellar objects

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Ph.D dissertation directed by: Dr. César Briceño

Ph.D degree awarded: March 2011

The results of the detection and characterization of brown dwarfs (BD) and very low mass stars (VLMS) in the dispersed populations of the Orion star forming region are presented. This work is based on a deep optical R and I-band photometric survey covering an area of ~ 200 deg^2 of the Orion OB1 association and complemented with near-infrared J, H and K-band photometry from the 2MASS and VISTA surveys. Combining optical and near-infrared magnitudes we identify respectively ~ 10000 y ~ 3000 candidates to VLMS and BD belonging to Orion OB1, with estimated masses within $0.01 < M/M_{\odot} < 0.5$ and mean ages of 6.5 Myr for the Orion OB1a sub-region and 3.2 Myr for the Orion OB1b sub-region. The photometric survey was complemented by low-resolution optical spectroscopy of photometric candidates covering a total area of ~ 8 deg^2, allowing the confirmation of ~ 300 new members with spectral types within M2 and M7.5.

The characterization of the VLMS and BD populations was performed in terms of its spatial distribution, mass function, number fraction of objects showing infrared excesses from circumstellar disks and the number fraction of objects showing accretion signatures. We found that spatial distributions of VLMS and BD follow similar patterns. A total of 13 spatial overdensities were detected, eight of which do not have positions coincident with known stellar groups, being possible new sub-structures within Orion OB1. Additionally, we found no correlation within the spatial distribution of massive stars and the spatial distribution of VLMS and BD. We found that the mass functions in Orion OB1a and OB1b are reasonably well described by Kroupa-type functions with $\alpha \sim -2$ or log-normal functions with coefficients $M_C \sim 0.12$ and $\sigma \sim 0.2$. We derived disk number fractions of $\sim 11\%$ in OB1b and $\sim 3\%$ in OB1a for VLMS, and $\sim 25\%$ in OB1b and $\sim 9\%$ in OB1a for BD. Accretion as measured by the strength of the Hα emission line yields accretor fractions of $\sim 8\%$ in OB1b and $\sim 3\%$ in OB1a for VLMS, while for BD we find that $\sim 25\%$ in OB1b and $\sim 3\%$ in OB1a are accreting.

Our results support the idea that from the models proposed for explaining the formation of VLMS and BD, the premature ejection of protostellar embryos and the photo-erosion of cores in HII regions are not dominant mechanisms. Additionally, the similarity within the mass function obtained for the sub-regions of Orion OB1 and those obtained by other authors in the majority of star-forming regions and young clusters, supports the idea of a universal mass function in the low-mass regime, confirming the known excess in the number of BDs predicted by some gravitational fragmentation models and supporting the mass functions predicted by some turbulent fragmentation models. Finally, the number fraction of VLMS and BD having circumstellar disks and/or showing accretion signatures decreases in a fraction of ~ 2 during the period within ~ 3 Myr and ~ 7 Myr, suggesting the similarity within the mean characteristic time scales in the evolution of disks around VLMS and BD.

Evolution of polycyclic aromatic hydrocarbons and the physics and chemistry of photodissociation regions: a combined infrared and millimeter study

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Ph.D degree awarded: November 2010

Polycyclic Aromatic Hydrocarbons (PAHs) are a major constituent of interstellar matter, containing about 20% of the total carbon in our Galaxy. PAHs are known to play a major role in the chemistry and the physics of photodissociation regions (PDRs). In these environments, the evolution of PAHs is driven by the UV field and it has been proposed to be linked to that of very small dust particles and small molecular hydrocarbons. In this work, we provide further insights into these evolutionary scenarios by combining the analysis of infrared (IR) data from ISO, Spitzer and AKARI space telescopes with new observations in the far-IR and sub-mm domains obtained with Herschel as well as in the millimeter domain using the IRAM ground-based telescopes.

I have developed a new analysis method for the mid-IR spectro-imagery observations that allows to study the photoprocessing of evaporating Very Small Grains (eVSGs) in PDRs. This procedure provides an estimate of the fraction of carbon locked in eVSGs compared to all atoms in the AIB carriers. This quantity is found to be related to the UV radiation field and can therefore be used as a tracer of its intensity in both resolved and unresolved sources. The obtained results are also consistent with a scenario in which eVSGs are destroyed by the UV field, giving birth to free PAHs. The results of the mid-IR analysis are compared with near-IR and millimeter observations, showing that the destruction process of eVSGs may be a source of production of small hydrocarbons. An accurate modeling of hydrocarbon chemistry in PDRs is needed to quantitatively test this scenario.

We used the IRAM 30 m telescope to search for the specific rotational signatures of an individual PAH, corannulene, in the millimeter spectrum of the Red Rectangle nebula. The comparison of the derived upper limit for detection with models allows to constrain the maximum abundance of small PAHs in this source. This provides evidence that these small species are under-abundant in the envelopes of evolved carbon stars and constrains the formation mechanisms of PAHs in these environments.

The results of the mid-IR analysis are combined with observations of several gas species in the far-IR and submillimeter with Herschel and in the millimeter with IRAM to study the geometry, energetics, and dynamics of the PDRs in the reflection nebula NGC 7023. Further progresses on this topics await for more Herschel data but also for the forthcoming JWST and SPICA space missions and the ALMA interferometer.

Two Postdoctoral Researchers in Galactic and Extra-galactic Star Formation (Ref. No. 11-04)

The Max Planck Institute for Astronomy (MPIA) in Heidelberg is seeking two highly motivated and qualified postdoctoral researchers to work in the new Max Planck Research Group 'Star Formation throughout the Milky-Way Galaxy' to be led by Dr. Thomas Robitaille starting in January 2012.

The group will work at the exciting interface between Galactic and extra-galactic star formation research, making use of the wealth of recent large-scale multi-wavelength surveys of the Milky-Way to study forming stars and star formation regions throughout the Galaxy, to better understand and quantify the processes that lead to and regulate Galactic star formation, and to provide a stepping stone for studying star formation in galaxies other than our own.

Specific group projects will include compiling and analyzing multi-wavelength data for tens of thousands of forming stars across the Galaxy, conducting follow-up observations of subsets of sources and clusters, carrying out radiative transfer and population synthesis modeling of forming stars and star formation regions, comparing the properties of forming stars and their environments, and using star formation regions in our Galaxy to study those in other galaxies in the local universe. As well as participating in some of these projects, successful candidates will be welcome and encouraged to develop their own research programs.

Applicants should have a PhD in Astronomy/Astrophysics or a related field. Previous experience in radiative transfer, hydrodynamical simulations, machine learning, and/or infrared observations (imaging or spectroscopic) is welcome but not required.

Each position will initially be for two years, with likely extension to three, starting January 1st 2012. Later starting dates are negotiable. Funds will be available to cover moving expenses, computer equipment, travel, and publications.

Applicants should send a curriculum vitae, a publication list, and a brief statement (up to 3 pages) describing achievements and future research plans and interests to robitaille *at* mpia-hd.mpg.de and should arrange for three letters of recommendation to be sent directly to the same e-mail address. All applications sent before August 1st, 2011 will receive full consideration, but the positions will remain open until suitable candidates are found.

For more information, please e-mail robitaille *at* mpia-hd.mpg.de

The remuneration is based on the German collective wage agreement for the public sector at the E13/14 level, and depends on qualification and experience. Social benefits are granted according to the regulations for public service (which includes health insurance, nursing care, pension, and unemployment insurance). The Max Planck Society is an equal opportunity employer. Applications from women, persons with disabilities, and minorities are particularly welcome. The MPIA supports its employees in the search for suitable child care institutions.

MW2011 – The Milky Way in the Herschel Era

Towards a Galaxy-scale view of the Star Formation Life-cycle

Rome, September 19-23 2011

Objectives:

The formation of stars is the event that shapes the fate of galaxies, and can be studied at best in our own Milky Way Galaxy. From low-mass to high-mass stellar regimes our comprehension of several of the critical steps in which this complex phenomenon unfolds, has been steadily improving over the past decades.

What remains still largely unexplored is a global perspective on Galactic star formation that can lead to a bottom-up model of the Galaxy as a star formation engine. Such a model would give solid physical foundation to commonly used prescriptions for star formation rates and efficiencies, providing the much needed link toward the extragalactic perspective.

By spring 2011 the major Galactic photometric surveys with Herschel will be completed, with high-quality data products starting to enter the public domain, allowing for the first time a high spatial resolution panoramic view of the Milky Way Galaxy over more than three decades in wavelength from the near infrared to the microwaves regime. The synergy with large-scale Galactic spectroscopic surveys of the atomic, molecular and ionised interstellar medium offers the unprecedented potential to paint a Galaxy-scale picture of the entire birth sequence of stars from the diffuse interstellar medium to the arrival of the forming stars on the Zero-Age Main Sequence.

Scientific Program:

The MW2011 conference will be structured in Sessions to promote advancement in a wide number of topics related to the Conference objectives.

* Session 1. An inventory of Galactic Surveys: scientific results of major continuum and spectroscopic Galactic surveys

* Session 2. The Milky Way in the Extragalactic Context

* Session 3. Morphology and physics of the diffuse interstellar medium: the agents shaping its properties.

* Session 4. From clouds to filaments, clumps and cores: conditions, mechanisms, properties and timescales for the formation of Galactic star forming structures.

* Session 5. Star formation modes, thresholds, rates and efficiency on Galactic scales.

* Session 6. Galactic structure. Distance determinations

We foresee stimulating formats for focused discussions, where current theoretical frameworks for each of the above topics will be critically reviewed in the light of the latest observational results. More details will be provided in the coming months.

Talks:

Each Conference Session features Review Talks (45 min), Invited Talks (30 min), Contributed Talks (20 min) and Posters.

Confirmed Invited Speakers: J. Bally, R. Benjamin, L. Blitz, I. Bonnell, F. Boulanger, P. Caselli, R. Cesaroni, R. Crutcher, P. Goldsmith, A. Goodman, P. Hennebelle, S. Inutsuka, C. Lada, S. Longmore, F. Motte, M. Meixner, K. Menten, N. Peretto, M. Pestalozzi, M. Reid, D. Russeil, E. Schinnerer, E. Schisano, J. Tan, A. Walsh, F. Wyrowski, A. Zavagno

Registration Fee & Deadline:

The Conference fee is 350 Euro. Registrations will be closed on September 1.

Venue:

The MW2011 Conference will be held in 19-23 September 2011 in Rome. The Conference venue is the "ANGELICUM" Conference Centre (www.angelicumcongress.it) in the prestigious "Pontificia Universit San Tommaso d'Aquino", conveniently located in the heart of Rome at walking distance from the "Colosseo" and the Roman Forum. The Centre features amphitheatre-style conference rooms, internal gardens and a wonderful XVIth century Cloister where you will enjoy Conference breaks and buffet lunches.

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Bruce Swinyard - UCL and STFC/RAL, Didcot (UK)
Leonardo Testi - INAF/OAA, Arcetri (Itaaaly) and ESO Hq., Garching (Germany)
Annie Zavagno - LAM, Marseille (France)

Further information is available on the conference website at **http://mw2011.ifsi-roma.inaf.it**

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Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each issue of the newsletter. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm
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