THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 190 — 7 October 2008 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

Abstracts of recently accepted papers

A Survey for a Coeval, Comoving Group Associated with HD 141569

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We present results of a search for a young stellar moving group associated with the star HD 141569, a nearby, isolated Herbig AeBe primary member of a 5±3 Myr-old triple star system on the outskirts of the Sco-Cen complex. Our spectroscopic survey identified a population of 21 Li-rich, <30 Myr-old stars within 30° of HD 141569 which possess similar proper motions with the star. The spatial distribution of these Li-rich stars, however, is not suggestive of a moving group associated with the HD 141569 triplet, but rather this sample appears cospatial with Upper Scorpius and Upper Centaurus Lupus. We apply a modified moving cluster parallax method to compare the kinematics of these youthful stars with Upper Scorpius and Upper Centaurus Lupus. Eight new potential members of Upper Scorpius and five new potential members of Upper Centaurus Lupus are identified. A substantial moving group with an identifiable nucleus within 15° (∼30 pc) of HD 141569 is not found in this sample. Evidently, the HD 141569 system formed ∼5 Myr ago in relative isolation, tens of parsecs away from the recent sites of star formation in the Ophiucus-Scorpius-Centaurus region.

Accepted by The Astronomical Journal

http://arxiv.org/abs/0809.3289

[Ne II] emission line profiles from photoevaporative disc winds

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I model profiles of the [Ne II] forbidden emission line at 12.81μm, emitted by photoevaporative winds from discs around young, solar-mass stars. The predicted line luminosities ($\sim 10^{-6}\mathrm{L}_{\odot}$) are consistent with recent data, and the line profiles vary significantly with disc inclination. Edge-on discs show broad (30–40 $\mathrm{km\,s^{-1}}$) double-peaked profiles, due to the rotation of the disc, while in face-on discs the structure of the wind results in a narrower line ($\simeq 10\,\mathrm{km\,s^{-1}}$) and a significant blue-shift (5–10 $\mathrm{km\,s^{-1}}$). These results suggest that observations of [Ne II] line profiles can provide a direct test of models of protoplanetary disc photoevaporation.

Accepted for publication in MNRAS Letters.

Preprint available at `http://www.strw.leidenuniv.nl/~rda/publications.html` or `arXiv:0809.0316`

First 450 μm dust continuum mapping of the massive star-forming region NGC 3576 with the P-ArTéMiS bolometer camera

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Context. The earliest phases of massive star formation are currently much debated.
Aims. In an effort to make progress, we took a census of Class 0-like protostellar dense cores in the NGC 3576 region, one of the nearest and most luminous embedded sites of high-mass star formation in the Galaxy.
Methods. We used the P-ArTéMiS bolometer camera on the APEX telescope to produce the first 450 μm dust continuum map of the filamentary dense clump associated with NGC 3576.
Results. Combining our 450 μm observations with existing data at other wavelengths, we have identified seven massive protostellar sources along the NGC 3576 filament and placed them in the M_{env}–L_{bol} evolutionary diagram for protostars.
Conclusions. Comparison with theoretical evolutionary tracks suggests that these seven protostellar sources will evolve into massive stars with masses $M_\star \sim 15$–$50\,M_\odot$. Four sources are classified as candidate high-mass Class 0 objects, two sources as massive Class I objects, and one source appears to be at an intermediate stage.

Accepted by Astronomy and Astrophysics (Letters)

http://arxiv.org/abs/0809.3968

The nature of the methanol maser ring G23.657−00.127. I. The distance through trigonometric parallax measurements

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Methanol masers are associated with young high-mass stars and are an important tool for investigating the process of massive star formation. The recently discovered methanol maser ring in G23.657−00.127 provides an excellent "laboratory" for a detailed study of the nature and physical origin of methanol maser emission, as well as parallax and proper motion measurements. Multi-epoch observations of the 12.2 GHz methanol maser line from the ring were conducted using the Very Long Baseline Array. Interferometric observations with milliarcsecond resolution enabled us to track single maser spots in great detail over a period of 2 years. We have determined the trigonometric parallax of G23.657−00.127 to be 0.313 ± 0.039 mas, giving a distance of $3.19^{+0.46}_{-0.35}$ kpc. The proper motion of the source indicates that it is moving with the same circular velocity as the LSR, but it shows a large peculiar motion of ≈ 35 km s^{-1} toward the Galactic center.

Accepted by Astronomy and Astrophysics

http://arxiv.org/abs/0809.1948

The Detection of Low Mass Companions in Hyades Cluster Spectroscopic Binary Stars

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We have observed a large sample of spectroscopic binary stars in the Hyades Cluster, using high resolution infrared spectroscopy to detect low mass companions. We combine our double-lined infrared measurements with well constrained orbital parameters from visible light single-lined observations to derive dynamical mass ratios. Using these results, along with photometry and theoretical mass-luminosity relationships, we estimate the masses of the individual components in our binaries. In this paper we present double-lined solutions for 25 binaries in our sample, with mass ratios from 0.1-0.8. This corresponds to secondary masses as small as 0.15 Msun. We include here our preliminary detection of the companion to vB 142, with a very small mass ratio of q=0.06+-0.04; this indicates that the companion may be a brown dwarf. This paper is an initial step in a program to produce distributions of mass ratio and secondary mass for Hyades cluster binaries with a wide range of periods, in order to better understand binary star formation. As such, our emphasis is on measuring these distributions, not on measuring precise orbital parameters for individual binaries.

Accepted by ApJ

http://arxiv.org/abs/0808.3393

Gravitational Fragmentation and the Formation of Brown Dwarfs in Stellar Clusters

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We investigate the formation of brown dwarfs and very low mass stars through the gravitational fragmentation of infalling gas into stellar clusters. The gravitational potential of a forming stellar cluster provides the focus that attracts gas from the surrounding molecular cloud. Structures present in the gas grow, forming filaments flowing into the cluster centre. These filaments attain high gas densities due to the combination of the cluster potential and local self-gravity. The resultant Jeans masses are low, allowing the formation of very low mass fragments. The tidal shear and high-velocity dispersion present in the cluster preclude any subsequent accretion, thus resulting in the formation of brown dwarfs or very low mass stars. Ejections are not required as the brown dwarfs enter the cluster with high relative velocities, suggesting that their disc and binary properties should be similar to that of low-mass stars. This mechanism requires the presence of a strong gravitational potential due to the stellar cluster implying that brown-dwarf formation should be more frequent in stellar clusters than in distributed populations of young stars. Brown dwarfs formed in isolation would require another formation mechanism such as due to turbulent fragmentation.

Published by Monthly Notices of the Royal Astronomical Society (Vol. 389, p. 1556)

Simultaneous Triggered Collapse of the Presolar Dense Cloud Core and Injection of Short-Lived Radioisotopes by a Supernova Shock Wave

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Cosmochemical evidence for the existence of short-lived radioisotopes (SLRI) such as ^{26}Al and ^{60}Fe at the time of the formation of primitive meteorites requires that these isotopes were synthesized in a massive star and then incorporated into chondrites within $\sim 10^6$ yr. A supernova shock wave has long been hypothesized to have transported the SLRI to the presolar dense cloud core, triggered cloud collapse, and injected the isotopes. Previous numerical calculations have shown that this scenario is plausible when the shock wave and dense cloud core are assumed to be isothermal at $\sim$ 10 K, but not when compressional heating to $\sim$ 1000 K is assumed. We show here for the first time that when calculated with the FLASH2.5 adaptive mesh refinement (AMR) hydrodynamics code, a 20 km/sec shock wave can indeed trigger the collapse of a 1 $M_\odot$ cloud while simultaneously injecting shock wave isotopes into the collapsing cloud, provided that cooling by molecular species such as H_2O, CO_2, and H_2 is included. These calculations imply that the supernova trigger hypothesis is the most likely mechanism for delivering the SLRI present during the formation of the solar system.

Accepted by Astrophys. J. Letters

Preprint available at http://www.dtm.ciw.edu/boss/ftp/simult

Proper Motions of Thermal Radio Sources near HH 7-11 in the NGC 1333 Star Forming Region

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Star forming regions are expected to show linear proper motions due to the relative motion of the Sun with respect to the region. These proper motions appear superposed to the proper motions expected in features associated with mass ejection from the young stellar objects embedded in them. Therefore, it is necessary to have a good knowledge of the proper motions of the region as a whole in order to correctly interpret the motions associated with mass ejection. In this paper we present the first direct measurement of proper motions of the NGC 1333 star forming region. This region harbors one of the most studied Herbig-Haro systems, HH 7-11, whose exciting source remains unclear. Using VLA A configuration data at 3.6 cm taken over 10 years, we have been able to measure the absolute proper motions of four thermal sources embedded in NGC 1333. From our results we have derived the mean proper motions of the NGC 1333 star forming region to be $\mu_\alpha \cos\delta = 9 \pm 1$ mas yr^{-1} and $\mu_\delta = -10 \pm 2$ mas yr^{-1}. In this paper, we also discuss the possible implications of our results in the identification of the outflow exciting sources.

Accepted by The Astronomical Journal

http://arxiv.org/abs/0809.0315

Survey of ortho-H_2D^+ ($1_{1,0}$–$1_{1,1}$) in dense cloud cores

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Aims. We present a survey of the ortho–$H_2D^+(1_{1,0}–1_{1,1})$ line toward a sample of 10 starless cores and 6 protostellar cores, carried out at the Caltech Submillimeter Observatory. The high diagnostic power of this line is revealed for the study of the chemistry, and the evolutionary and dynamical status of low-mass dense cores.
Methods. The derived ortho–H_2D^+ column densities ($N(ortho-H_2D^+)$) are compared with predictions from simple chemical models of centrally concentrated cloud cores.
Results. The line is detected in 7 starless cores and in 4 protostellar cores. $N(ortho-H_2D^+)$ ranges between 2 and $40{\times}10^{12}$ cm^{-2} in starless cores and between 2 and $9{\times}10^{12}$ cm^{-2} in protostellar cores. The brightest lines are detected toward the densest and most centrally concentrated starless cores, where the CO depletion factor and the deuterium

fractionation are also largest. The large scatter observed in plots of $N(ortho - \mathrm{H_2D^+})$ vs. the observed deuterium fractionation and vs. the CO depletion factor is likely to be due to variations in the ortho–to–para (o/p) ratio of H_2D^+ from > 0.5 for $T_{\rm kin} < 10$ K gas in pre–stellar cores to $\simeq 0.03$ (consistent with $T_{\rm kin} \simeq 15$ K for protostellar cores). The two Ophiuchus cores in our sample also require a relatively low o/p ratio ($\simeq 0.3$). Other parameters, including the cosmic-ray ionization rate, the CO depletion factor (or, more in general, the depletion factor of neutral species), the volume density, the fraction of dust grains and PAHs also largely affect the ortho–H_2D^+ abundance. In particular, gas temperatures above 15 K, low CO depletion factors and large abundance of negatively charged small dust grains or PAHs drastically reduce the deuterium fractionations to values inconsistent with those observed toward pre–stellar and protostellar cores. The most deuterated and H_2D^+–rich objects (L 429, L 1544, L 694-2 and L 183) are reproduced by chemical models of centrally concentrated (central densities $\simeq 10^6$ cm^{-3}) cores with chemical ages between 10^4 and 10^6 yr. Upper limits of the para-$H_3O^+(1_1^-–2_1^+)$ and para–$D_2H^+(1_{1,0}–1_{0,1})$ lines are also given. The upper limit to the para-H_3O^+ fractional abundance is $\simeq 10^{-8}$ and we find an upper limit to the para–D_2H^+/ortho–H_2D^+ column density ratio equal to 1, consistent with chemical model predictions of high density (2×10^6 cm^{-3}) and low temperature ($T_{\rm kin}$ < 10 K) clouds.
Conclusions. Our results point out the need for better determinations of temperature and density profiles in dense cores as well as for observations of para-H_2D^+.

Accepted by Astronomy & Astrophysics

http://xxx.lanl.gov/abs/0809.2803

SMA CO (2–1) Observations of CG 30: A Protostellar Binary System with a High-Velocity Quadrupolar Molecular Outflow

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We present interferometric observations in the ^{12}CO (2–1) line and at 1.3 mm dust continuum of the low-mass protostellar binary system in the cometary globule CG 30, using the Submillimeter Array. The dust continuum images resolve two compact sources (CG 30N and CG 30S), with a linear separation of $\sim$8700 AU and total gas masses of ~ 1.4 and $\sim 0.6\,M_\odot$, respectively. With the CO images, we discover two high-velocity bipolar molecular outflows, driven by the two sources. The two outflows are nearly perpendicular to each other, showing a quadrupolar morphology. The northern bipolar outflow extends along the southeast (redshifted, with a velocity up to $\sim 23\,{\rm km\,s^{-1}}$) and northwest (blueshifted, velocity up to $\sim 30\,{\rm km\,s^{-1}}$) directions, while the southern pair has an orientation from southwest (blueshifted, velocity up to $\sim 13\,{\rm km\,s^{-1}}$) to northeast (redshifted, velocity up to $\sim 41\,{\rm km\,s^{-1}}$). The outflow mass of the northern pair, driven by the higher mass source CG 30N, is ~ 9 times larger than that of the southern pair. The discovery of the quadrupolar molecular outflow in the CG 30 protobinary system, as well as the presence of other quadrupolar outflows associated with binary systems, demonstrate that the disks in (wide) binary systems are not necessarily co-aligned after fragmentation.

Accepted by ApJL

http://arXiv.org/abs/0809.2624

Centimeter Polarimetry of the R Coronae Australis Region

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Circularly polarized 3.5 cm continuum emission was detected toward three radio sources in the R CrA region using the Very Large Array. The Class I protostar IRS 5b persistently showed polarized radio emission with a constant helicity over 8 yr, which suggests that its magnetosphere has a stable configuration. There is a good correlation between the Stokes I and Stokes V fluxes, and the fractional polarization is about 0.17. During active phases the fractional polarization is a weakly decreasing function of Stokes I flux, which suggests that IRS 5b is phenomenologically similar to other types of flare stars such as RS CVn binaries. The variability timescale of the polarized flux is about a month, and the magnetosphere of IRS 5b must be very large in size. The Class I protostar IRS 7A was detected once in circularly polarized radio emission, even though IRS 7A drives a thermal radio jet. This detection implies that the radio emission from the magnetosphere of a young protostar can escape the absorption by the partially ionized wind at least once in a while. The properties of IRS 7A and IRS 5b suggests that Class I protostars have organized peristellar magnetic fields of a few kilogauss and that the detectability of magnetospheric emission may depend on the evolutionary status of protostar. Also reported is the detection of circularly polarized radio emission toward the variable radio source B5.

Accepted by ApJ

http://minho.kasi.re.kr/Publications.html ; http://arxiv.org/abs/0809.3839

Color Gradients Detected in the HD 15115 Circumstellar Disk

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We report *HST* NICMOS coronagraphic images of the HD 15115 circumstellar disk at 1.1 μm. We find a similar morphology to that seen in the visible and at H band—an edge-on disk that is asymmetric in surface brightness. Several aspects of the 1.1 μm data are different, highlighting the need for multiwavelength images of each circumstellar disk. We find a flattening to the western surface brightness profile at 1.1 μm interior to $2''$ (90 AU) and a warp in the western half of the disk. We measure the surface brightness profiles of the two disk lobes and create a measure of the dust scattering efficiency between 0.55 and 1.65 μm at $1''$, $2''$, and $3''$. At $2''$ the western lobe has a neutral spectrum up to 1.1 μm and a strong absorption or blue spectrum >1.1 μm, while a blue trend is seen in the eastern lobe. At $1''$ the disk has a red $F11W{-}H$ color in both lobes.

Published by The Astrophysical Journal Letters (Vol. 684, p. L41)

Coagulation of small grains in disks: the influence of residual infall and initial small-grain content

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Turbulent coagulation in protoplanetary disks is known to operate on timescale far shorter than the lifetime of the disk. In the absence of mechanisms that replenish the small dust grain population, protoplanetary disks would rapidly lose their continuum opacity-bearing dust. This is inconsistent with infrared observations of disks around T Tauri stars and Herbig Ae/Be stars, which are usually optically thick at visual wavelengths and show signatures of small ($a \lesssim 3\mu$m) grains. A plausible replenishing mechanism of small grains is collisional fragmentation or erosion of large dust aggregates, which model calculations predict to play an important role in protoplanetary disks. If optically thick disks are to be seen as proof for ongoing fragmentation or erosion, then alternative explanations for the existence of optically thick disks must be studied carefully. In tis study we explore two scenarios. First, we study the effect of residual, low-level infall of matter onto the disk surface. We find that infall rates as low as $10^{-11}\mathrm{M}_\odot$/yr can, in principle, replenish the small grain population to a level that keeps the disk marginally optically thick. However, it

remains to be seen if the assumption of such inflow is realistic for star+disk systems at the age of several Myrs, at which winds and jets are expected to have removed any residual envelope. The effectiveness of even a low level infall can be understood by the strongly non-linear behavior of the coagulation equation: a high, fine-grain, dust density at any given time leads to very, effective removal of these small grains, while a low fine-grain density lasts for a far longer time. We then consider a second scenario in which, during the buildup phase of the disk, an intermediate fine-grain dust abundance is generated that is sufficiently low to ensure longevity of the state yet sufficiently high for the disk to remain optically thick. While our models confirm that such an "initial condition" can be constructed, we argue that these special initial conditions cannot be achieved during the disk build-up phase. In summary, fragmentation or erosion still appear to be the most promising processes to explain the abundant presence of small grains in old disks.

Accepted by Astronomy and Astrophysics

http://www.astro.uva.nl/~dominik/preprints/trickle.pdf

Spectrophotometric Analysis of the T Tauri Star GQ Lupi A

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Context. GQ Lup A is a classical T Tauri star that shows clear signs of accretion through the presence of inverse P Cygni profiles in its main emission lines. Recently, Neuhäuser et al. (2005, A&A, 435, L13) found a co-moving sub-stellar companion of GQ Lup A, raising the importance of determining precise stellar parameters, system age, and distance to GQ Lup.
Aims. Our main objective is to use spectrophotometric time series to determine GQ Lup A stellar parameters and predict its photospheric spectral distribution. The excess spectral luminosity can then be measured and employed to test predictions of magnetospheric accretion models of classical T Tauri stars.
Methods. We present the analysis of 18 spectrophotometric observations of the T Tauri star GQ Lup A (K7) obtained with the Boller & Chivens spectrograph at the 1.52 m ESO telescope in La Silla. We also revisited archival photometric data of this star, comparing previous light curve variability with our more recent data.
Results. We determined the photospheric flux of GQ Lup A on each observing night and obtained the stellar radius ($R_* = 1.8 \pm 0.3\ R_\odot$), adopting a mean distance of 150 ± 20 pc to the Lupus 1 cloud. Assuming a K7 V temperature of 4060 K, the luminosity of GQ Lup A is $L_* = 0.8 \pm 0.3\ L_\odot$. Standard evolutionary models indicate a stellar mass of $M_* = 0.8 \pm 0.2\ M_\odot$ and an age of 3 ± 2 Myr. GQ Lup A spectral lines are consistent with a projected rotational velocity of $v \sin i = 6.5 \pm 2.0$ km s^{-1}. We measured the excess emission — veiling — and used the resulting photospheric spectral distribution to calculate a stellar extinction (A_V) of 0.5 ± 0.1. The veiling was found to be variable and periodic at 10.7 ± 1.6 days, which is consistent with the period of GQ Lup A obtained from archival B band photometric data (10.43 ± 0.12 days). The star exhibits strong emission lines with substantial variability in flux. The emission line fluxes are strongly correlated with one another but not with veiling.

Published by Astronomy & Astrophysics (Vol. 489, p. 349)

Cavities in inner disks: the GM Aurigae case

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Recent modeling based on unresolved infrared observations of the spectral energy distribution (SED) of GM Aurigae suggests that the inner disk of this single TTauri star is truncated at an inner radius of 25 AU. We attempt to find evidence of this inner hole in the gas distribution, using spectroscopy with high angular resolution. Using the IRAM array, we obtained high angular resolution (∼ 1.5”) observations with a high S/N per channel of the 13CO J=2-1, C18O J=2-1 and of the 13CO J=1-0 lines. A standard parametric disk model is used to fit the line data in the Fourier-plane and to derive the CO disk properties. Our measurement is based on a detailed analysis of the spectroscopic profile from the CO disk rotating in Keplerian velocity. The millimeter continuum, tracing the dust, is also analyzed. We detect an inner cavity of radius 19 ± 4 AU at the 4.5σ level. The hole manifests itself by a lack of emission beyond the (projected) Keplerian speed at the inner radius. We also constrain the temperature gradient in the disk. Our data reveal the existence of an inner hole in GM Aur gas disk. Its origin remains unclear, but can be linked to planet formation or to a low mass stellar companion orbiting close to the central star (∼ 5-15 AU). The frequent finding of inner cavities suggests that either binarity is the most common scenario of star formation in Taurus or that giant planet formation starts early.

Accepted by Astronomy & Astrophysics Letters

Properties of the Youngest Protostars in Perseus, Serpens, and Ophiuchus

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We present an unbiased census of deeply embedded protostars in Perseus, Serpens, and Ophiuchus, assembled by combining large-scale 1.1 mm Bolocam continuum and *Spitzer* Legacy surveys. We identify protostellar candidates based on their mid-infrared properties, correlate their positions with 1.1 mm core positions from Enoch et al. (2006), Young et al. (2006), and Enoch et al. (2007), and construct well-sampled SEDs using our extensive wavelength coverage ($\lambda = 1.25 - 1100$ μm). Source classification based on the bolometric temperature yields a total of 39 Class 0 and 89 Class I sources in the three cloud sample. We compare to protostellar evolutionary models using the bolometric temperature-luminosity diagram, finding a population of low luminosity Class I sources that are inconsistent with constant or monotonically decreasing mass accretion rates. This result argues strongly for episodic accretion during the Class I phase, with more than 50% of sources in a “sub-Shu” ($dM/dt < 10^{-6}$ $M_\odot$ yr^{-1}) accretion state. Average spectra are compared to protostellar radiative transfer models, which match the observed spectra fairly well in Stage 0, but predict too much near-IR and too little mid-IR flux in Stage I. Finally, the relative number of Class 0 and Class I sources are used to estimate the lifetime of the Class 0 phase; the three cloud average yields a Class 0 lifetime of $1.7 \pm 0.3 \times 10^5$ yr, ruling out an extremely rapid early accretion phase. Correcting photometry for extinction results in a somewhat shorter lifetime (1.1×10^5 yr). In Ophiuchus, however, we find very few Class 0 sources ($N_{\rm Class\ 0}/N_{\rm Class\ I} \sim 0.1 - 0.2$), similar to previous studies of that cloud. The observations suggest a consistent picture of nearly constant *average* accretion rate through the entire embedded phase, with accretion becoming episodic by at least the Class I stage, and possibly earlier.

Accepted by ApJ

http://xxx.lanl.gov/abs/0809.4012

The structure of the protoplanetary disk surrounding three young intermediate mass stars. II. Spatially resolved dust and gas distribution

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Aims. We present the first direct comparison of the distribution of the gas, as traced by the [O I] 6300Å emission, and the dust, as traced by the 10 μm emission, in the planet-forming region of proto-planetary disks around three intermediate-mass stars: HD 101412, HD 135344 B and HD 179218.

Method. N-band visibilities were obtained with VLTI/MIDI. Simple geometrical models are used to compare the dust emission to high-resolution optical spectra in the 6300 Å [O I] line of the same targets.

Results. HD 101412 and HD 135344 B show compact (< 2 AU) 10 μm emission while the [O I] brightness profile shows a double peaked structure. The inner peak is strongest and is consistent with the location of the dust, the outer peak is fainter and is located at 5-10 AU. In both systems, spatially extended PAH emission is found. HD 179218 shows a double ring-like 10 μm emission with the first ring peaking at $\sim$ 1 AU and the second at $\sim$ 20 AU. The [O I] emitting region is more compact, peaking between 3 – 6 AU.

Conclusions. The disks around HD 101412 and HD 135344 B appear strongly flared in the gas, but self-shadowed in the dust beyond $\sim$ 2 AU. The difference in the gas and dust vertical structure beyond 2 AU might be the first observational evidence of gas-dust decoupling in protoplanetary disks. The disk around HD 179218 is flared in the dust. The 10 μm emission emerges from the inner rim and from the flared surface of the disk at larger radii. No dust emission is detected between $\sim$ 3 – 15 AU. The oxygen emission seems also to come from a flared structure, however, the bulk of this emission is produced between $\sim$ 1 – 10 AU. This could indicate a lack of gas in the outer disk or could be due to chemical effects which reduce the abundance of OH – the parent molecule of the observed [O I] emission – further away from the star. It may also be a contrast effect if the [O I] emission is much stronger in the inner disk. We suggest that the three systems, HD 179218, HD 135344 B and HD 101412, may form an evolutionary sequence: the disk initially flared becomes flat under the combined action of gas-dust decoupling, grain growth and dust settling.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/0809.3947

A multi-wavelength study of a double intermediate-mass protostar – from large-scale structure to collimated jets

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Aims: The earliest stages of intermediate- and high-mass star formation remain poorly understood. To gain deeper insights, we study a previously discovered protostellar source that is deeply embedded and drives an energetic molecular outflow.Methods: The source, UYSO 1, located close to IRAS 07029–1215 at a distance of about 1 kpc, was observed in the (sub)millimeter and centimeter wavelength ranges, as well as at near-, mid-, and far-infrared wavelengths.Results: The multi-wavelength observations resulted in the detection of a double intermediate-mass protostar at the location of UYSO 1. In addition to the associated molecular outflow, with a projected size of 0.25 pc, two intersecting near-infrared jets with projected sizes of 0.4 pc and 0.2 pc were found. However, no infrared counterparts to the driving sources could be detected in sensitive near- to far-infrared observations (including *Spitzer*). In interferometric millimeter observations, UYSO 1 was resolved into two continuum sources with high column densities ($> 10^{24}$ cm^{-2}) and gas masses of 3.5 $M_\odot$ and 1.2 $M_\odot$, with a linear separation of 4200 AU. We report the discovery of an H_2O maser toward one of the two sources. Within an appropriate multi-wavelength coverage, the total luminosity is roughly estimated to be ≈50 $L_\odot$, shared by the two components, one of which is driving the molecular outflow that has a dynamical timescale of less than a few thousand years. The jets of the two individual components are not aligned. Submillimeter observations show that the region lacks the typical hot-core chemistry.Conclusions: We find two protostellar objects, whose associated circumstellar and parent core masses are high enough to suggest that they may evolve into intermediate-mass stars. This is corroborated by their association with a very massive and energetic CO outflow, suggesting high protostellar accretion rates. The short dynamical timescale of the outflow, the pristine chemical composition of the cloud core and absence of hot core tracers, the absence of detectable radio continuum emission, and the very low protostellar luminosity argue for an extremely early evolutionary stage.

Accepted by A&A

http://arxiv.org/abs/0809.5048

Spitzer's Mid-Infrared View on an Outer-Galaxy Infrared Dark Cloud Candidate toward NGC 7538

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Infrared dark clouds (IRDCs) represent the earliest observed stages of clustered star formation, characterized by large column densities of cold and dense molecular material observed in silhouette against a bright background of mid-IR emission. Up to now, IRDCs were predominantly known toward the inner Galaxy where background infrared emission levels are high. We present Spitzer observations with the Infrared Array Camera toward object G111.80+0.58 (G111) in the outer Galactic plane, located at a distance of ∼3 kpc from us and ∼10 kpc from the Galactic center. Earlier results show that G111 is a massive, cold molecular clump very similar to IRDCs. The mid-IR Spitzer observations unambiguously detect object G111 in absorption. We have identified for the first time an IRDC in the outer Galaxy, which confirms the suggestion that cluster-forming clumps are present throughout the Galactic plane. However, against a low mid-IR background such as the outer Galaxy it takes some effort to find them.

Accepted by The Astrophysical Journal Letters (Vol. 685 L51)

http://arxiv.org/abs/0808.2053

A new modified-rate approach for gas-grain chemical simulations

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Context: Understanding grain-surface processes is crucial to interpreting the chemistry in many regions of the interstellar medium. However, accurate surface chemistry models are computationally expensive and are difficult to integrate with gas-phase simulations.
Aims: A new modified-rate method for solving grain-surface chemical systems is presented. The purpose of the method is to trade a small amount of accuracy, and certain excessive detail, for the ability to accurately model highly complex systems that can otherwise only be treated using the sometimes inadequate rate-equation approach.
Methods: In contrast to previous rate-modification techniques, the functional form of the surface production rates was modified, and not simply the rate coefficient. This form is appropriate to the extreme "small-grain" limit, and can be verified using an analytical master-equation approach. Various further modifications were made to this basic form, to account for competition between processes, to improve estimates of surface occupation probabilities, and to allow a switch-over to the normal rate equations where these are applicable.
Results: The new method was tested against a number of systems solved previously using master-equation and Monte

Carlo techniques. It is found that even the simplest method is quite accurate, and a great improvement over rate equations. Further modifications allow the master-equation results to be reproduced exactly for the methanol-producing system, within computational accuracy. Small discrepancies arise when non-zero activation energies are assumed for the methanol system, which result from complex reaction-competition processes that cannot be resolved easily without using exact methods. Inaccuracies in computed abundances are never greater than a few tens of percent, and typically of the order of one percent, in the most complex systems tested.
Conclusions: The new modified-rate approach presented here is robust to a range of grain-surface parameters, and accurately reproduces the results of exact methods. Furthermore, it may be derived from basic approximations, making the behaviour of the system understandable in terms of physical processes rather than time-dependent probabilities or other more abstract quantities. The method is simple enough to be easily incorporated into a full gas-grain chemical code. Implementation of the method in simple networks, including hydrogen-only systems, is trivial, whilst the results are highly accurate.

Accepted by Astronomy & Astrophysics

arXiv: 0809.2934

Modeling the magnetic field in the protostellar source NGC 1333 IRAS 4A

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Context. Magnetic fields are believed to play a crucial role in the process of star formation.
Aims. We compare high-angular resolution observations of the submillimeter polarized emission of NGC 1333 IRAS 4A, tracing the magnetic field around a low-mass protostar, with models of the collapse of magnetized molecular cloud cores.
Methods. Assuming a uniform dust alignment efficiency, we computed the Stokes parameters and synthetic polarization maps from the model density and magnetic field distribution by integrations along the line-of-sight and convolution with the interferometric response.
Results. The synthetic maps are in good agreement with the data. The best-fitting models were obtained for a protostellar mass of 0.8 $M_\odot$, of age 9×10^4 yr, formed in a cloud with an initial mass-to-flux ratio ~ 2 times the critical value.
Conclusions. The magnetic field morphology in NGC 1333 IRAS 4A is consistent with the standard theoretical scenario for the formation of solar-type stars, where well-ordered, large-scale, rather than turbulent, magnetic fields control the evolution and collapse of the molecular cloud cores from which stars form.

Accepted by Astronomy & Astrophysics Letters

http://arxiv.org/abs/0809.5278

Photoevaporation of Circumstellar Disks by FUV, EUV and X-ray Radiation from the Central Star

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We calculate the rate of photoevaporation of a circumstellar disk by energetic radiation (FUV, 6eV $< h\nu <$13.6eV; EUV, 13.6eV $< h\nu <$0.1keV; and Xrays, $h\nu >$ 0.1keV) from its central star. We focus on the effects of FUV and X-ray photons since EUV photoevaporation has been treated previously, and consider central star masses in the range $0.3 - 7\mathrm{M}_\odot$. Contrary to the EUV photoevaporation scenario, which creates a gap at about $r_g \sim 7$ $(M_*/1\mathrm{M}_\odot)$ AU and then erodes the outer disk from inside out, we find that FUV photoevaporation predominantly removes less bound gas from the outer disk. Heating by FUV photons can cause significant erosion of the outer disk where most of the mass is typically located. X-rays indirectly increase the mass loss rates (by a factor ~ 2) by ionizing the gas, thereby reducing the positive charge on grains and PAHs and enhancing FUV-induced grain photoelectric heating. FUV and X-ray photons may create a gap in the disk at ~ 10 AU under favourable circumstances. Photoevaporation timescales for $M_* \sim 1M_\odot$ stars are estimated to be $\sim 10^6$ years, after the onset of disk irradiation by FUV and X-rays. Disk lifetimes do not vary much for stellar masses in the range $0.3 - 3M_\odot$. More massive stars ($\gtrsim 7M_\odot$) lose their disks rapidly (in $\sim 10^5$ years) due to their high EUV and FUV fields. Disk lifetimes are shorter for shallow surface density distributions and when the dust opacity in the disk is reduced by processes such as grain growth or settling. The latter suggests that the photoevaporation process may accelerate as the dust disk evolves.

Accepted by Astrophysical Journal

astroph: 0890.1494

The origin of short-lived radionuclides and the astrophysical environment of solar system formation

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Based on early solar system abundances of short-lived radionuclides (SRs), such as ^{26}Al ($T_{1/2} = 0.74$ Myr) and ^{60}Fe ($T_{1/2} = 1.5$ Myr), it is often asserted that the Sun was born in a large stellar cluster, where a massive star contaminated the protoplanetary disk with freshly nucleosynthesized isotopes from its supernova (SN) explosion. To account for the inferred initial solar system abundances of short-lived radionuclides, this supernova had to be close (~ 0.3 pc) to the young ($\lesssim 1$ Myr) protoplanetary disk. Here we show that massive star evolution timescales are too long, compared to typical timescales of star formation in embedded clusters, for them to explode as supernovae within the lifetimes of nearby disks. This is especially true in an Orion Nebular Cluster (ONC)-type of setting, where the most massive star will explode as a supernova ~ 5 Myr after the onset of star formation, when nearby disks will have already suffered substantial photoevaporation and/or formed large planetesimals. We quantify the probability for *any* protoplanetary disk to receive SRs from a nearby supernova at the level observed in the early solar system. Key constraints on our estimate are: (1) SRs have to be injected into a newly formed ($\lesssim 1$ Myr) disk, (2) the disk has to survive UV photoevaporation, and (3) the protoplanetary disk must be situated in an enrichment zone permitting SR injection at the solar system level without disk disruption. The probability of protoplanetary disk contamination by a supernova ejecta is, in the most favorable case, 3×10^{-3}.

Accepted by ApJ (680, 781)

http://dx.doi.org/10.1086/587613

Spectropolarimetric Observations of Herbig Ae/Be Stars. II. Comparison of Spectropolarimetric Surveys: HAeBe, Be and Other Emission-Line Stars.

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The polarization of light across individual spectral lines contains information about the circumstellar environment on very small spatial scales. We have obtained a large number of high precision, high resolution spectropolarimetric observations of Herbig Ae/Be, Classical Be and other emission-line stars collected on 117 nights of observations with the HiVIS spectropolarimeter at a resolution of R=13000 on the 3.67m AEOS telescope. We also have many observations from the ESPaDOnS spectropolarimeter at a resolution of R=68000 on the 3.6m CFH telescope. In roughly $\sim$2/3 of the so-called "windy" or "disky" Herbig Ae/Be stars, the detected H_α linear polarization varies from our typical detection threshold near 0.1% to over 2%. In all but one HAe/Be star the detected polarization effect is not coincident with the H_α emission peak but is detected in and around the obvious absorptive part of the line profile. The qu-loops are dominated by the polarization in this absorptive region. In several stars the polarization varies in time mostly in the absorptive component and is not necessarily tied to corresponding variations in intensity. This is a new result not seen at lower resolution. In the Be and emission-line stars, 10 out of a sample of 30 show a typical broad depolarization

effect but 4 of these 10 show weaker effects only visible at high resolution. Another 5 of 30 show smaller amplitude, more complex signatures. Six stars of alternate classification showed large amplitude (1-3%) absorptive polarization effects. These detections are largely inconsistent with the traditional disk-scattering and depolarization models.

Accepted by ApJS

http://arxiv.org/abs/0809.3849

The Unusual Object IC 2144 / MWC 778

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IC 2144 is a small reflection nebula located in the zone of avoidance near the Galactic anticenter. It has been investigated here largely on the basis of Keck/HIRES optical spectroscopy (R $\sim$ 48,000) and a SpeX spectrogram of the near-IR (R $\sim$ 2,000) obtained at the NASA Infrared Telescope Facility. The only star in the nebula that is obvious in the optical or near-IR is the peculiar emission-line object MWC 778 (V = 12.8), which resembles a T Tauri star in some respects. What appear to be F- or G-type absorption features are detectable in its optical region under the very complex emssion-line spectrum; their radial velocity agrees with the CO velocity of the larger cloud in which IC 2144 is embedded. There are significant differences between the spectrum of the brightest area of the nebula and of MWC 778, the presumed illuminator. The distance of IC 2144 is inferred to be about 1.0 kpc by reference to other star-forming regions in the vicinity. The extinction is large, as demonstrated by [Fe II] emission-line ratios in the near-IR and the strength of the diffuse interstellar band spectrum; a provisional value of A(V) of 3.0 mag was assumed. The SED of MWC 778 rises steeply beyond about 1 μm, with a slope characteristic of a Class I source. Integration of the flux distribution leads to an IR luminosity of about 510 $L_\odot$. If MWC 778 is indeed an F- or G-type pre-main sequence star several magnitudes above the ZAMS, a population of faint emission-Hα stars would be expected in the vicinity. Such a search, like other investigations that are recommended in this paper, has yet to be carried out.

Accepted by Astronomical Journal

Preprints: astro-ph arXiv:0809.4252

Water, O_2 and Ice in Molecular Clouds

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We model the temperature and chemical structure of molecular clouds as a function of depth into the cloud, assuming a cloud of constant density n illuminated by an external FUV (6 eV $< h\nu <$ 13.6 eV) flux G_0 (scaling factor in multiples of the local interstellar field). Extending previous photodissociation region models, we include the freezing of species, simple grain surface chemistry, and desorption (including FUV photodesorption) of ices. We also treat the opaque cloud interior with time-dependent chemistry. Here, under certain conditions, gas phase elemental oxygen freezes out as water ice and the elemental C/O abundance ratio can exceed unity, leading to complex carbon chemistry. Gas phase H_2O and O_2 peak in abundance at intermediate depth into the cloud, roughly $A_V \sim 3-8$ from the surface, the depth proportional to $\ln(G_0/n)$. Closer to the surface, molecules are photodissociated. Deeper into the cloud, molecules freeze to grain surfaces. At intermediate depths photodissociation rates are attenuated by dust extinction, but photodesorption prevents total freezeout. For $G_0 < 500$, abundances of H_2O and O_2 peak at values $\sim 10^{-7}$, producing columns $\sim 10^{15}$ cm^{-2}, independent of G_0 and n. The peak abundances depend primarily on the product of the photodesorption yield of water ice and the grain surface area per H nucleus. At higher values of G_0, thermal desorption of O atoms from grains enhances the gas phase H_2O peak abundance and column slightly, whereas the gas phase O_2 peak abundance rises to $\sim 10^{-5}$ and the column to $\sim 2\times10^{16}$ cm^{-2}. We present simple analytic equations

for the abundances as a function of depth which clarify the dependence on parameters. The models are applied to observations of H_2O, O_2, and water ice in a number of sources, including B68, NGC 2024, and ρ Oph.

Accepted by Astrophysical Journal

http://arxiv.org/abs/0809.1642

Evolution of Massive Protostars with High Accretion Rates

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Formation of massive stars by accretion requires a high accretion rate of $> 10^{-4} M_\odot$/yr to overcome the radiation pressure barrier of the forming stars. Here, we study evolution of protostars accreting at such high rates, by solving the structure of the central star and the inner accreting envelope simultaneously. The protostellar evolution is followed starting from small initial cores until their arrival at the stage of the Zero-Age Main Sequence (ZAMS) stars. An emphasis is put on evolutionary features different from those with a low accretion rate of $10^{-5} M_\odot$/yr, which is presumed in the standard scenario for low-mass star formation. With the high accretion rate of $10^{-3} M_\odot$/yr, the protostellar radius becomes very large and exceeds $100 R_\odot$. It is not until the stellar mass reaches $40 M_\odot$ that hydrogen burning begins and the protostar reaches the ZAMS phase, and this ZAMS arrival mass increases with the accretion rate. At a very high accretion rate of $> 3 \times 10^{-3} M_\odot$/yr, the total luminosity of the protostar becomes so high that the resultant radiation pressure inhibits the growth of the protostars under steady accretion before reaching the ZAMS stage. Therefore, the evolution under the critical accretion rate $3 \times 10^{-3} M_\odot$/yr gives the upper mass limit of possible pre-main-sequence stars at $60 M_\odot$. The upper mass limit of MS stars is also set by the radiation pressure onto the dusty envelope under the same accretion rate at $250 M_\odot$. We also propose that the central source enshrouded in the Orion KL/BN nebula has effective temperature and luminosity consistent with our model, and is a possible candidate for such protostars growing under the high accretion rate.

Accepted by ApJ

astro-ph/0806.4122

Self-Consistent Simulations of Star Cluster Formation from Gas Clouds Under the Influence of Galaxy-Scale Tidal Fields

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We present the first results of a project aimed at following the formation and long-term dynamical evolution of star clusters within the potential of a host galaxy. Here, we focus on a model evolved within a simplified potential representing the Large Magellanic Cloud. This demonstrates for the first time the self-consistent formation of a bound star cluster from a giant molecular cloud. The model cluster reproduces the density profiles and structural characteristics of observed star clusters.

Published by Monthly Notices of the Royal Astronomical Society (Vol. 389, p. L61)

The Large Magellanic Cloud's Largest Molecular Cloud Complex: *Spitzer* Analysis of Embedded Star Formation

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We present a mid-infrared analysis of star-formation activity in the Large Magellanic Cloud's molecular ridge (south of 30 Doradus). The Magellanic Clouds are a rare laboratory in which extragalactic star-formation diagnostics can be tested at high spatial resolution. The southern part of the molecular ridge is particularly interesting as a potential extreme in the range of molecular cloud conditions, because of the apparent paucity (in optical tracers) of star formation compared to its gas mass. Our *Spitzer* observations are sensitive to protostars $> \sim 3\ M_\odot$, and we estimate a total star-formation luminosity of $5 \times 10^6\ L_\odot$ in $2 \times 10^6\ M_\odot$ of molecular material. Detailed modeling of individual infrared-detected star-formation regions yields a total mass of star formation in the region consistent with that predicted by the gas surface density via the Schmitt-Kennicutt relation. The star-formation activity is distributed in rather low-luminosity regions, so the total star-formation rate determined by our infrared analysis is higher than would be predicted simply by the total Hα and 24 μm luminosities. Detailed analysis in very nearby galaxies, like the Magellanic Clouds, allows us to test and better understand the scaling relations used in unresolved and distant star-formation regions. Finally, we analyze the star-formation regions in the context of their individual molecular clouds and find that clouds with a higher ratio of CO mass to virial mass are more vigorously forming stars.

Published by The Astronomical Journal (Vol. 136, p. 1442)

Dynamical evolution and spectral characteristics of the stellar group Mamajek 2

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The dynamical evolution of the recently detected stellar group Mamajek 2 is studied by means of its past 3D orbit. The past orbits of the open clusters NGC 2516 and α Persei, belonging to the so-called "Local Association", were also computed in order to check for a possible common past dynamical evolution of these systems. To complete the data of the Mamajek 2 small group, we have obtained high resolution FEROS spectra to measure the radial and also the projected rotational velocities of its members; an estimate of its metallicity was obtained as well. Two exceptionally low rotating A-type stars turned out to be a strong magnetic Ap star in one case, and a normal A0 star with near-solar metallicity in the other. The dynamical results showed that NGC 2516 and Mamajek 2 may have had a common origin at the age of 135 $\pm$ 5 Myr. This dynamical age confirms the individual ages of 140 Myr for NGC 2516 and 120 $\pm$ 25 Myr for Mamajek 2 obtained independently by photometric methods. Both these groups appear to have the same solar metallicity giving support to a common birth scenario. The dynamical approach is showing that some bound open clusters can form in a coeval fashion with unbound stellar groups or with associations.

Accepted by The Astrophysical Journal

Binary frequency of very young brown dwarfs at separations smaller than 3 AU

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Searches for companions of brown dwarfs by direct imaging probe mainly orbital separations greater than 3–10 AU. On the other hand, previous radial velocity surveys of brown dwarfs are mainly sensitive to separations smaller than 0.6 AU. It has been speculated if the peak of the separation distribution of brown dwarf binaries lies right in the

unprobed range. The present work for the first time extends high-precision radial velocity surveys of brown dwarfs out to 3 AU. Based on more than six years UVES/VLT spectroscopy the binary frequency of brown dwarfs and (very) low-mass stars (M4.25-M8) in Chamaeleon I was determined: it is 18^{+20}_{-12} % for the whole sample and 10^{+18}_{-8} % for the subsample of ten brown dwarfs and very low-mass stars (M$\leq$ 0.1 $M_\odot$). Two spectroscopic binaries were confirmed, these are the brown dwarf candidate Cha Hα 8 (previously discovered by Joergens & Müller), and the low-mass star CHXR 74. separations appear to be 1 AU or greater, the binary frequency at <1 AU might be less than 10%. Now for the first time companion searches of (young) brown dwarfs cover the whole orbital separation range and the following observational constraints for models of brown dwarf formation can be derived: (i) the frequency of brown dwarf and very low-mass stellar binaries at <3 AU is not significantly exceeding that at >3 AU; i.e. direct imaging surveys do not miss a significant fraction of brown dwarf binaries; (ii) the overall binary frequency of brown dwarfs and very low-mass stars is 10-30 %; (iii) the decline of the separation distribution of brown dwarfs towards smaller separations seem to occur between 1 and 3 AU; (iv) the observed continuous decrease of the binary frequency from the stellar to the substellar regime is confirmed at <3 AU providing further evidence for a continuous formation mechanism from low-mass stars to brown dwarfs.

Accepted by A&A

http://www.mpia.de/homes/joergens/refpublications.html

PAH Emission from Herbig Ae/Be Stars

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We present spectra of a sample of Herbig Ae and Be (HAeBe) stars obtained with the Infrared Spectrograph on *Spitzer*. All but one of the Herbig stars show emission from PAHs, and seven of the spectra show PAH emission, but no silicate emission at 10 μm. The central wavelengths of the 6.2, 7.78.2, and 11.3 μm emission features decrease with stellar temperature, indicating that the PAHs are less photoprocessed in cooler radiation fields. The apparent low level of photoprocessing in HAeBe stars, relative to other PAH emission sources, implies that the PAHs are newly exposed to the UVoptical radiation fields from their host stars. HAeBe stars show a variety of PAH emission intensities and ionization fractions but a narrow range of PAH spectral classifications based on positions of major PAH feature centers. This may indicate that, regardless of their locations relative to the stars, the PAH molecules are altered by the same physical processes in the protoplanetary disks of intermediate-mass stars. Analysis of the mid-IR SEDs indicates that our sample likely includes both radially flared and more flattened/settled disk systems, but we do not see the expected correlation of overall PAH emission with disk geometry. We suggest that the strength of PAH emission from HAeBe stars may depend not only on the degree of radial flaring but also on the abundance of PAHs in illuminated regions of the disks and possibly on the vertical structure of the inner disk as well.

Published by The Astrophysical Journal (Vol. 684, p. 411)

Outflow and Infall in a Sample of Massive Star Forming Regions. II. Large-Scale Kinematics

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We present maps of seven sources selected from our previous paper in SiO (J = 8–7) and HCO^+ and $H^{13}CO^+$ (J =

4–3), which were obtained using HARP-B on the James Clerk Maxwell Telescope. We find that four out of our seven sources have infall signatures based on their HCO^+ emission profiles. From our maps, we have determined the extent of both the outflowing and infalling regions toward these sources, and constrained the amount of infalling and outflowing mass, as well as the mass infall rate for each massive star forming region. From our SiO observations, we estimate the source luminosity required to shock the surroundings of these massive star forming regions and find luminosities similar to those of the H ii regions themselves. We find that the ratio between our infall and outflow masses is less than 1, suggesting high mass entrainment rates in the molecular outflows. We also find that the large-scale molecular infall rate toward G10.60.4 is comparable to the small-scale molecular infall rate found in previous studies.

Published by The Astrophysical Journal (Vol. 684, 1273)

Oscillations of MHD shock waves on the surfaces of T Tauri stars

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This work treats the matter deceleration in a magnetohydrodynamics radiative shock wave at the surface of a star. The problem is relevant to classical T Tauri stars where infalling matter is channeled along the star's magnetic field and stopped in the dense layers of photosphere. A significant new aspect of the present work is that the magnetic field has an arbitrary angle with respect to the normal to the star's surface. We consider the limit where the magnetic field at the surface of the star is not very strong in the sense that the inflow is super Alfvénic. In this limit the initial deceleration and heating of plasma (at the entrance to the cooling zone) occurs in a fast magnetohydrodynamic shock wave. To calculate the intensity of radiative losses we use "real" and "power-law" radiative functions. We determine the stability/instability of the radiative shock wave as a function of parameters of the incoming flow: velocity, strength of the magnetic field, and its inclination to the surface of the star. In a number of simulation runs with the "real" radiative function, we find a simple criterion for stability of the radiative shock wave. For a wide range of parameters, the periods of oscillation of the shock wave are of the order $0.02 - 0.2$ s.

Accepted by MNRAS (vol. 388, pp 357-366, 2008)

Spatial Distributions of Young Stars

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We analyze the spatial distributions of young stars in Taurus-Auriga and Upper Sco as determined from the two-point correlation function (i.e. the mean surface density of neighbors). The corresponding power-law fits allow us to determine the fractal dimensions of each association's spatial distribution, measure the stellar velocity dispersions, and distinguish between the bound binary population and chance alignments of members. We find that the fractal dimension of Taurus is D$\sim$1.05, consistent with its filamentary structure. The fractal dimension of Upper Sco may be even shallower (D$\sim$0.7), but this fit is uncertain due to the limited area and possible spatially-variable incompleteness. We also find that random stellar motions have erased all primordial structure on scales of <0.07 degrees in Taurus and <1.7 degrees in Upper Sco; given ages of $\sim$1 Myr and $\sim$5 Myr, the corresponding internal velocity dispersions are $\sim$0.2 km/s and $\sim$1.0 km/s, respectively. Finally, we find that binaries can be distinguished from chance alignments at separations of <120" (17000 AU) in Taurus and <75" (11000 AU) in Upper Sco. The binary populations in these associations that we previously studied, spanning separations of 3-30", are dominated by binary systems. However, the few lowest-mass pairs ($M_{prim} < 0.3 M_{sun}$) might be chance alignments.

Accepted by Astrophysical Journal Letters (Vol 686, p. L111)

http://adsabs.harvard.edu/abs/2008arXiv0809.0893K

A Multi-Epoch HST Study of the Herbig-Haro Flow from XZ Tauri

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We present nine epochs of *Hubble Space Telescope* optical imaging of the bipolar outflow from the pre-main sequence binary XZ Tauri. Our data monitors the system from 1995 – 2005 and includes emission line images of the flow. The northern lobe appears to be a succession of bubbles, the outermost of which expanded ballistically from 1995 – 1999 but in 2000 began to deform and decelerate along its forward edge. It reached an extent of 6 arcsec from the binary in 2005. A larger and fainter southern counterbubble was detected for the first time in deep ACS images from 2004. Traces of shocked emission are seen as far as 20 arcsec south of the binary. The bubble emission nebulosity has a low excitation overall, as traced by the [S II]/Hα line ratio, requiring a nearly comoving surrounding medium that has been accelerated by previous ejections or stellar winds.

Within the broad bubbles there are compact emission knots whose alignments and proper motions indicate that collimated jets are ejected from each binary component. The jet from the southern component, XZ Tau A, is aligned with the outflow axis of the bubbles and has tangential knot velocities of 70 – 200 km s^{-1}. Knots in the northern flow are seen to slow and brighten as they approach the forward edge of the outermost bubble. The knots in the jet from the other star, XZ Tau B, have lower velocities of $\sim$ 100 km s^{-1}.

To explain the observations of the outer bubble, we propose that the XZ Tau A stellar jet underwent a large velocity pulse circa 1980. This ejection quickly overtook older, slower-moving ejecta very near the star, producing a $\sim$ 70 km s^{-1} shock in a hot (T$\sim$ 80,000 K), compact "fireball". The initial thermal pressure of this gas parcel drove the expansion of a spherical bubble. Subsequent cooling caused the bubble to transition to ballistic expansion, followed by slowing of its forward edge by mass-loading from the pre-shock medium. Repeated pulses may explain the multiple bubbles seen in the data. Collimated jets continue to flow through the bubble's interior, and with the fading of the original fireball they are becoming the primary energizing mechanism for the emission line structures. Future evolution of the flow should see the outer bubble structures fade from view, and the emergence of a more typical Herbig-Haro jet/bowshock morphology. We present a preliminary numerical model of a pulsed jet to illustrate this scenario.

Accepted by The Astronomical Journal

http://lanl.arxiv.org/abs/0809.2073

Lynds 1622: a nearby star forming cloud projected on Orion B?

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We present results of optical spectroscopic and photometric observation of the pre-main sequence stars associated with the cometary shaped dark cloud Lynds 1622, and ^{12}CO and ^{13}CO observations of the cloud. We determined the effective temperatures and luminosities of 14 pre-main sequence stars associated with the cloud from their positions in the Hertzsprung–Russell diagram, as well as constructed their spectral energy distributions using optical, 2MASS and *Spitzer* IRAC and MIPS data. We derived physical parameters of L 1622 from the molecular observations. Our results are not compatible with the assumption that L 1622 lies on the near side of the Orion–Eridanus loop, but suggest that L 1622 is as distant as Orion B. At a distance of 400 pc the mass of the cloud, derived from our ^{12}CO data, is 1100 $M_{\odot}$, its star formation efficiency is $\sim$ 1.8%, and the average age of its low-mass pre-main sequence star population is about 1 million years.

Accepted by MNRAS

http://arxiv.org/abs/0809.4754

Integral Field Spectroscopy of HH 262: The Spectral Atlas

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HH 262 is a group of emitting knots displaying an "hour-glass" morphology in the Hα and [S II] lines, located 3.5 arcmin to the northeast of the young stellar object L1551-IRS5, in Taurus. We present new results of the kinematics and physical conditions of HH 262 based on Integral Field Spectroscopy covering a field of $\sim 1.5 \times 3$ arcmin^2, which includes all the bright knots in HH 262. These data show complex kinematics and significant variations in physical conditions over the mapped region of HH 262 on a spatial scale of ≤ 3 arcsec. A new result derived from the IFS data is the weakness of the [N II] emission (below detection limit in most of the mapped region of HH 262), including the brightest central knots. Our data reinforce the association of HH 262 with the redshifted lobe of the evolved molecular outflow L1551-IRS5. The interaction of this outflow with a younger one, powered by L1551 NE, around the position of HH 262 could give rise to the complex morphology and kinematics of HH 262.

Accepted by Monthly Notices of the Royal Astronomical Society

http://es.arxiv.org/abs/0809.3969

The UKIDSS Galactic Plane Survey

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The UKIDSS Galactic Plane Survey (GPS) is one of the five near infrared Public Legacy Surveys that are being undertaken by the UKIDSS consortium, using the Wide Field Camera on the United Kingdom Infrared Telescope. It is surveying 1868 deg^2 of the northern and equatorial Galactic plane at Galactic latitudes $-5<b<5$ in the J, H and K filters and a $\sim$200 deg^2 area of the Taurus-Auriga-Perseus molecular cloud complex in these three filters and the 2.12 um (1-0) H_2 filter. It will provide data on $\sim 2\times10^9$ sources. Here we describe the properties of the dataset and provide a user's guide for its exploitation. We also present brief Demonstration Science results from DR2 and from the Science Verification programme. These results illustrate how GPS data will frequently be combined with data taken in other wavebands to produce scientific results. The Demonstration Science comprises six studies. (1) A GPS/Spitzer-GLIMPSE cross match for the star formation region G28.983-0.603 to identify YSOs. This increases the number of YSOs identified by a factor of ten compared to GLIMPSE alone. (2) A wide field study of the M17 nebula, in which an extinction map of the field is presented and the effect of source confusion on luminosity functions in different sub-regions is noted. (3) H_2 emission in the rho Ophiuchi dark cloud. All the molecular jets are traced back to a single active clump containing only a few protostars, which suggests that the duration of strong jet activity and associated rapid accretion in low mass protostars is brief. (4) X-ray sources in the Nuclear Bulge. The GPS data

distinguishes local main sequence counterparts with soft X-ray spectra from Nuclear Bulge giant counterparts with hard X-ray spectra. (5) External galaxies in the Zone of Avoidance. The galaxies are clearly distinguished from stars in fields at longitudes $l > 90$. (6) IPHAS-GPS optical-infrared spectrophotometric typing. The (i'-J) vs.(J-H) diagram is used to distinguish A-F type dwarfs, G dwarfs, K dwarfs and red clump giants in a field with high reddening.

Accepted by MNRAS

http://lanl.arxiv.org/abs/0712.0100

Spectrophotometric Properties of Pre-Main-Sequence Stars: the ϵ Chamaeleontis Cluster

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We present a study of flux-calibrated low-resolution optical spectroscopy of 10 stars belonging to eight systems in the ∼5-Myr-old ϵ Chamaeleontis (ϵ Cha) pre-main-sequence (PMS) star cluster. Using synthetic broad-band colours, narrow-band continuum, atomic and molecular lines derived from the spectra, we compare the ϵ Cha stars to a slightly older PMS cluster, the ∼8-Myr-old η Cha cluster and to main-sequence dwarfs. Using synthetic VRI colours and other indices, we find that the relationship between broad-band colours and spectroscopic temperature indicators for ϵ Cha cluster members is indistinguishable from that of Gyr-old dwarfs. This result is identical to that found earlier in η Cha. Gravity-sensitive line indices place the cluster between the giant and dwarf sequences, and there is clear evidence that ϵ Cha stars have lower surface gravity than η Cha stars. This result is consistent with ϵ Cha being the slightly younger PMS association, a few Myr younger according to the HertzsprungRussell (HR) diagram placement of these two clusters and comparison with PMS evolutionary grids. Late M-type ϵ Cha cluster members show a B-band flux excess of ≈0.2 mag compared to observations of standard dwarfs, which might be related to enhanced magnetic activity. A similar level of excess B-band emission appears to be a ubiquitous feature of low-mass members of young stellar populations with ages less than a few hundred Myr, a very similar time-scale to the PMS phase of elevated relative X-ray luminosity.

Published by Monthly Notices of the Royal Astronomical Society (Vol. 389, p. 1461)

Angular Momentum Accretion onto a Gas Giant Planet

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We investigate the accretion of angular momentum onto a protoplanet system using three-dimensional hydrodynamical simulations. We consider a local region around a protoplanet in a protoplanetary disk with sufficient spatial resolution. We describe the structure of the gas flow onto and around the protoplanet in detail. We find that the gas flows onto the protoplanet system in the vertical direction crossing the shock front near the Hill radius of the protoplanet, which is qualitatively different from the picture established by two-dimensional simulations. The specific angular momentum of the gas accreted by the protoplanet system increases with the protoplanet mass. At Jovian orbit, when the protoplanet mass $M_{\rm p}$ is $M_{\rm p} < 1 M_{\rm J}$, where $M_{\rm J}$ is Jovian mass, the specific angular momentum increases as $j \propto M_{\rm p}$. On the other hand, it increases as $j \propto M_{\rm p}^{2/3}$ when the protoplanet mass is $M_{\rm p} > 1 M_{\rm J}$. The stronger dependence of the specific angular momentum on the protoplanet mass for $M_{\rm p} < 1 M_{\rm J}$ is due to thermal pressure of the gas. The estimated total angular momentum of a system of a gas giant planet and a circumplanetary disk is two-orders of magnitude larger than

those of the present gas giant planets in the solar system. A large fraction of the total angular momentum contributes to the formation of the circumplanetary disk. We also discuss the satellite formation from the circumplanetary disk.

Accepted by The Astrophysical Journal (Vol. 685, p.1220)

http://arxiv.org/abs/0801.3305

Magneto-hydrodynamics of Population III Star Formation

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Jet driving and fragmentation processes in a collapsing primordial cloud are studied using three-dimensional MHD nested grid simulations. Starting from a rotating magnetized spherical cloud with a number density of $n_c \simeq 10^3\,\mathrm{cm}^{-3}$, we follow the evolution of the cloud until the adiabatic core (or protostar) formation epoch, $n_c \simeq 10^{22}\,\mathrm{cm}^{-3}$. We calculate 36 models parameterizing the initial magnetic γ_0 and rotational β_0 energies. The evolution of collapsing primordial clouds is characterized by the ratio of the initial rotational energy to the magnetic energy, γ_0/β_0. The Lorentz force significantly affects cloud evolution when $\gamma_0 > \beta_0$, while the centrifugal force dominates than the Lorentz force when $\beta_0 > \gamma_0$. When the cloud rotates rapidly with an angular velocity of $\Omega_0 > 10^{-17}(n_c/10^3\ \mathrm{cm}^{-3})^{2/3}\,\mathrm{s}^{-1}$ and $\beta_0 > \gamma_0$, fragmentation occurs before protostar formation, but no jet appears after protostar formation. On the other hand, when the initial cloud has the magnetic field of $B_0 > 10^{-9}(n_c/10^3\,\mathrm{cm}^{-3})^{2/3}\,\mathrm{G}$ and $\gamma_0 > \beta_0$, a strong jet appears after protostar formation without fragmentation. Our results indicate that Population III protostars frequently show fragmentation and protostellar jets. Population III stars are therefore born as binary or multiple stellar systems; as in present-day star formation, they can drive strong jets that disturb the interstellar medium significantly, and thus they may induce the formation of next generation stars.

Accepted by The Astrophysical Journal (Vol. 685, p. 690)

http://arxiv.org/abs/0803.1224

Search for HH objects and emission stars in star formation regions. IV. New Herbig-Haro flows and objects associated with cometary nebulae

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As part of a project to search for new Herbig-Haro (HH) objects in star formation regions, observations are reported on the neighborhoods of five cometary nebulae: MacC H12, MacC sH15, GM 1-14, RNO 33, and Pars 17. We have been able to identify 9 previously unknown HH objects in those regions. Almost all of these objects belong to directed flows whose sources are, with high probability, the central stars of these nebulae. In the cases of MacC H12 and GM 1-14, the outflows have a distinct bipolar structure. The sources of the outflows are located on a J-H/H-K diagram in order to classify them.

Accepted by Astrophysics

Present-Day Star Formation at High Galactic Altitude: The Tidal Encounter Paradigm

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The Galaxy harbors a population of high Galactic altitude clouds (HGACs) which are, in some cases, similar to those in the disk. About 3% of open clusters younger than 100 Myr are located at least 200 pc away from the disk; in the outer Galaxy, some embedded clusters are found at 500 pc. But, by what mechanism could star clusters form far from the regions in which the usual driving forces of triggered star formation can act efficiently? In this Letter we investigate whether passing preexisting star clusters can induce tidal forces able to trigger star formation in HGACs. The interaction is studied using the impulse approximation and results are compared with available evidence. Our analytical estimate indicates that this mechanism is able to induce star formation if passing clusters are massive enough, i.e., globular clusters. The expected number of interactions appears to be consistent with the observed star formation rate at high Galactic altitude.

Published by The Astrophysical Journal Letters (Vol. 685, p. L125)

Early-Type Objects in NGC 6611 and the Eagle Nebula

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Aims. An important question about Be stars is whether they are born as such or whether they have become Be stars during their evolution. It is necessary to observe young clusters to answer this question.
Methods. To this end, observations of stars in NGC 6611 and the star-formation region of Eagle Nebula were carried out with the ESO-WFI in slitless spectroscopic mode and at the VLT-GIRAFFE ($R \simeq 6400$–17000). The targets for the GIRAFFE observations were pre-selected from the literature and our catalogue of emission-line stars based on the WFI study. GIRAFFE observations allowed us to study the population of the early-type stars accurately both with and without emission lines. For this study, we determined the fundamental parameters of OBA stars thanks to the GIRFIT code. We also studied the status of the objects (main sequence or pre-main sequence stars) by using IR data, membership probabilities, and location in HR diagrams.
Results. The nature of the early-type stars with emission-line stars in NGC 6611 and its surrounding environment is derived. The slitless observations with the WFI clearly indicate a small number of emission-line stars in M16. We observed with GIRAFFE 101 OBA stars, among them 9 are emission-line stars with circumstellar emission in Hα. We found that W080 could be a new He-strong star, like W601. W301 is a possible classical Be star, W503 is a mass-transfer eclipsing binary with an accretion disk, and the other ones are possible Herbig Ae/Be stars. We also found that the rotational velocities of main sequence B stars are 18% lower than those of pre-main sequence B stars, in good agreement with theory about the evolution of rotational velocities. Combining adaptive optics, IR data, spectroscopy, and radial velocity indications, we found that 27% of the B-type stars are binaries. We also redetermined the age of NGC 6611 found equal to 1.2–1.8 Myrs, in good agreement with the most recent determinations.

Published by Astronomy & Astrophysics (Vol. 489, p. 459)

Spatially Resolved Near-Infrared Spectroscopy of the Massive Star-Forming Region IRAS 19410+2336

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Aims. IRAS 19410+2336 is a young massive star forming region with an intense outflow activity. Outflows are

frequently studied in the near-infrared (NIR) since the H_2 emission in this wavelength range often traces the shocked molecular gas. However, the mechanisms behind the H_2 emission detected in IRAS 19410+2336 have not been clarified yet. We present here spatially resolved NIR spectroscopy which allows us to verify whether the H_2 emission originates from thermal emission in shock fronts or from fluorescence excitation by non-ionizing UV photons. Moreover, NIR spectroscopy also offers the possibility of studying the characteristics of the putative driving source(s) of the H_2 emission by the detection of photospheric and circumstellar spectral features, and of the environmental conditions (e.g. extinction).
Methods. We obtained long-slit, intermediate-resolution, NIR spectra of IRAS 19410+2336 using LIRIS, the NIR imager/spectrograph mounted on the 4.2 m William Herschel Telescope. As a complement, we also obtained J, H and K_S images with the Las Campanas 2.5 m Du Pont Telescope, and archival mid-infrared (MIR) *Spitzer* images at 3.6, 4.5, 5.8 and 8.0 μm.
Results. We confirm the shocked nature of the H_2 emission, with an excitation temperature of about 2000 K, based on the analysis of relevant H_2 line ratios, ortho-to-para ratios and excitation diagrams. We have also identified objects with very different properties and evolutionary stages in IRAS 19410+2336. The most massive source at millimeter wavelengths, mm1, with a mass of a few tens of solar masses, has a bright NIR (and MIR) counterpart. This suggests that emission — probably coming through a cavity created by one of the outflows present in the region, or from the outflow cavity itself — is leaking at these wavelengths. The second most massive millimeter source, mm2, is only detected at $\lambda > \sim 6$ μm, suggesting that it could be a high-mass protostar still in its main accretion phase. The NIR spectra of some neighboring sources show CO first-overtone bandhead emission which is associated with neutral material located in the inner regions of the circumstellar environment of YSOs.

Published by Astronomy and Astrophysics (Vol. 489, p. 229)

Searching for molecular hydrogen mid-infrared emission in the circumstellar environments of Herbig Be stars

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Context: Molecular hydrogen (H_2) is the most abundant molecule in the circumstellar (CS) environments of young stars, and is a key element in giant planet formation. The measurement of the H_2 content provides the most direct probe of the total amount of CS gas, especially in the inner warm planet-forming regions of the disks.

Aims: Most Herbig Be stars (HBes) are distant from the Sun and their nature and evolution are still debated. We therefore conducted mid-infrared observations of H_2 as a tracer of warm gas around HBes known to have gas-rich CS environments.

Methods: We report a search for the H_2 S(1) emission line at 17.0348μm in the CS environments of 5 HBes with the high resolution spectroscopic mode of *VISIR* (*ESO VLT Imager and Spectrometer for the mid-InfraRed*).

Results: No source shows evidence for H_2 emission at 17.0348μm. Stringent 3σ upper limits on the integrated line fluxes are derived. Depending on the adopted temperature, limits on column densities and masses of warm gas are also estimated. These non-detections constrain the amount of warm (> 150 K) gas in the immediate CS environments of our target stars to be less than $\sim 1 - 10 M_{\rm Jup}$.

Accepted by A&A (Research Note)

Time-Resolved AU-Scale Jets Traced by Masers in the IRAS 4A/B Regions of NGC 1333

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We present results of VLBI observations of the water masers associated with IRAS 4A and IRAS 4B in the NGC 1333 star-forming region taken in four epochs over a two month period. Both objects have been classified as extremely young sources, and each source is known to be a multiple system. Using the Very Long Baseline Array, we detected 35 masers in epoch I, 40 masers in epoch II, 35 in epoch III, and 24 in epoch IV. Only one identified source in each system is associated with these masers. These data are used to calculate proper motions for the masers and trace the jet outflows within 100 AU of IRAS 4A2 and IRAS 4BW. In IRAS 4A2 there are two groups of masers, one near the systemic cloud velocity and one redshifted. They expand linearly away from each other at velocities of 53 km s^{-1}. In IRAS 4BW, masers are observed in two groups that are blueshifted and redshifted relative to the cloud velocity. They form complex linear structures with a thickness of 3 mas (1 AU at a distance of 320 pc) that expand linearly away from each other at velocities of 78 km s^{-1}. Neither of the jet outflows traced by the maser groups align with the larger scale outflows. We suggest the presence of unresolved companions to both IRAS 4A2 and 4BW.

Published by The Astrophysical Journal (Vol. 685, p. 285)

The low-mass YSO CB230-A: investigating the protostar and its jet with NIR spectroscopy and Spitzer observations

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To investigate the earliest phases of star formation and study how newly-born stars interact with the surrounding medium, we performed a line and continuum survey at NIR and mm-wavelengths of a sample of relatively isolated Bok globules. We present a follow-up observational program of a star-forming site in the globule CB230. From narrow-band continuum observations of this site, we had discovered a bright [FeII] jet, which originates in the low-mass YSO CB230-A. We aim to investigate the physical properties of the region from where the jet is launched. Our analysis was carried out using low-resolution NIR spectra acquired with the camera NICS at the TNG telescope, with JH and HK grisms and a 1 arcsec-wide slit. These observational data were complemented with infrared photometric data from the Spitzer space telescope archive. The relevant physical properties of CB230-A were constrained by SED fitting of fluxes from the NIR to the mm. The YSO spectrum exhibits a significant number of atomic and molecular emission lines and absorption features. The characteristics of this spectrum suggest that we are observing a region in the close vicinity of CB230-A, i. e. its photosphere and/or an active accretion disk. The spectra of the knots in the jet contain a large number of emission lines, including a rich set of [FeII] lines. Emission due to H_2 and [FeII] are not spatially correlated, confirming that [FeII] and H_2 are excited by different mechanisms, in agreement with the models where [FeII] traces dissociative J-shocks and molecular hydrogen traces slower C-shocks. By using intensity ratios involving density-sensitive [FeII] lines, we estimated the electron densities along the jet to be 6×10^3–1×10^4 cm^{-3}. This indicates either high density post-shock regions of ionised gas or regions with a high degree of ionisation. By combining the present data with previously obtained maps at NIR- and mm-wavelengths, the emerging scenario is that CB230-A is a Class 0/I YSO driving an atomic jet that is observed to be almost monopolar probably due to its inclination to the plane of the sky and the resulting higher extinction of its red side. This primary jet appears to be sufficiently energetic to open the cavity visible in the NIR images and drive the large-scale molecular outflow observed at mm-wavelengths. CB230-A was revealed to be a good location to test the innermost structure of accreting low-mass protostars.

Accepted by Astronomy & Astrophysics

http://babbage.sissa.it/pdf/0809.1591

Magnetic Braking and Protostellar Disk Formation: The Ideal MHD Limit

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Magnetic fields are usually considered dynamically important in star formation when the dimensionless mass-to-flux ratio is close to, or less than, unity ($\lambda < \sim 1$). We show that, in disk formation, the requirement is far less stringent. This conclusion is drawn from a set of 2D (axisymmetric) simulations of the collapse of rotating, singular isothermal cores magnetized to different degrees. We find that a weak field corresponding to $\lambda \sim 100$ can begin to disrupt the rotationally supported disk through magnetic braking, by creating regions of rapid, supersonic collapse in the disk. These regions are separated by one or more centrifugal barriers, where the rapid infall is temporarily halted. The number of centrifugal barriers increases with the mass-to-flux ratio λ. When $\lambda > \sim 100$, they merge together to form a more or less contiguous, rotationally supported disk. Even though the magnetic field in such a case is extremely weak on the scale of dense cores, it is amplified by collapse and differential rotation, to the extent that its pressure dominates the thermal pressure in both the disk and its surrounding region. For relatively strongly magnetized cores with $\lambda < \sim 10$, the disk formation is suppressed completely, as found previously. A new feature is that the mass accretion is highly episodic, due to reconnection of the magnetic field lines accumulated near the center. For rotationally supported disks to appear during the protostellar mass accretion phase of star formation in dense cores with realistic field strengths, the powerful magnetic brake must be weakened, perhaps through nonideal MHD effects. Another possibility is to remove, through protostellar winds, the material that acts to brake the disk rotation. We discuss the possibility of observing a generic product of the magnetic braking, an extended circumstellar region that is supported by a combination of toroidal magnetic field and rotation — a "magnetogyrosphere"—interferometrically.

Published by The Astrophysical Journal (Vol. 681, p. 1356)

The Palomar/Keck Adaptive Optics Survey of Young Solar Analogs: Evidence for a Universal Companion Mass Function

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We present results from an adaptive optics survey for substellar and stellar companions to Sun-like stars. The survey targeted 266 F5–K5 stars in the 3 Myr to 3 Gyr age range with distances of 10–190 pc. Results from the survey include the discovery of two brown dwarf companions (HD 49197B and HD 203030B), 24 new stellar binaries, and a triple system. We infer that the frequency of 0.012–0.072 $M_\odot$ brown dwarfs in 28–1590 AU orbits around young solar analogs is $3.2^{+3.1}_{-2.7}\%$ (2σ limits). The result demonstrates that the deficiency of substellar companions at wide orbital separations from Sun-like stars is less pronounced than in the radial velocity "brown dwarf desert." We infer that the mass distribution of companions in 28–1590 AU orbits around solar-mass stars follows a continuous $dN/dM_2 \propto M_2^{-0.4}$ relation over the 0.01–1.0 $M_\odot$ secondary mass range. While this functional form is similar to the that for <0.1 $M_\odot$ isolated objects, over the entire 0.01–1.0 $M_\odot$ range the mass functions of companions and of isolated objects differ significantly. Based on this conclusion and on similar results from other direct imaging and radial velocity companion surveys in the literature, we argue that the companion mass function follows the same universal form over the entire range between 0–1590 AU in orbital semi-major axis and ≈0.01–20 $M_\odot$ in companion mass. In this context, the relative dearth of substellar versus stellar secondaries at *all* orbital separations arises naturally from the inferred form of the companion mass function.

Accepted by ApJ Supplements

Preprint available at: http://arxiv.org/abs/0808.2982

A Large-Scale ^{13}CO Mapping of the W49A Molecular Cloud Complex

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We present high angular resolution ^{13}CO (J=1–0) and C^{18}O (J=1–0) maps of the W49A molecular cloud complex. The entire $\sim 20' \times 20'$ area centered on the ultracompact HII region W49N-G was observed in the ^{13}CO line with a $17''$ (HPBW) resolution, while the central $\sim 3' \times 3'$ area was covered in C^{18}O. The ^{13}CO and C^{18}O line profiles toward W49N-G show a similar shape with a constant intensity ratio of 6, suggesting that both lines are optically thin. We identified 14 separate features (MHH-1 to MHH-14) from the ^{13}CO velocity channel maps, most of them distributed within an area $6'$ (20 pc) in diameter with their total mass amounting to 1.7×10^6 M$_\odot$. The features have a three dimensional velocity dispersion of 8 km s^{-1}, which leads to a mean free time per feature of 10^6 yr. This suggests that they are interacting one another in the region $\sim$20 pc in diameter. Among the features, MHH-1 corresponding to W49N is unique in that it exhibits a large velocity width (15 km s^{-1} FWHM) and is compact in size (2.3 pc $\times$ 3.0 pc FWHM) while containing a large mass of 2.4×10^5 M$_\odot$, which indicates the free fall time of MHH-1 of order 10^5 yr, an order of magnitude smaller than that of the entire complex. It has turned out that MHH-1 has a smaller spatial width at $V_{\rm LSR} \lesssim 8$ km s^{-1} than at $\gtrsim 8$ km s^{-1}. This result, together with the line profile characteristics of various optically thin lines, suggests that at least two massive clouds with different radial velocities exist toward MHH-1. The massive compact feature MHH-1 may have been produced by the interaction of the two velocity components, although published numerical simulations imply that a head-on collision is necessary between two clouds with different sizes and densities to form an unstable core.

Accepted by PASJ (Vol.61, No.1, February 25)

Integral spectroscopy of the nebula GM 1-29 and the star PV Cep

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Integral spectroscopy data for the nebula GM 1-29 and the source star PV Cep taken on the 2.6-m telescope at the Byurakan Observatory are presented. The structure and kinematics of a collimated emission outflow directed along the axis of the nebula are studied. Changes in the radial velocity and intensity of the absorption component of the nebular Hα line are observed and studied; these are interpreted as a result of an anisotropy in the stellar wind at distances on the order of several stellar radii, where this absorption is formed.

Accepted by Astrophysics

Searches for HH objects and emission stars in star formation regions. V. Two new cometary nebulae in Perseus

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A small region surrounding the emission star LkHa 326 in the Perseus dark cloud is studied in the optical range. Two new cometary nebulae are described and their relationship to the Herbig-Haro objects in this region is examined. An HH-jet is discovered near the central star of one of these nebulae. Six emission stars, of which four are new, are detected by slitless spectroscopy.

Accepted by Astrophysics

VLT/NACO and Subaru/CIAO JHK-Band High-Resolution Imaging Polarimetry of the Herbig Be Star R Monocerotis

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Aims. We investigate the dust properties of the disk and envelope of the Herbig Be star R Mon by means of near-infrared multiwavelength imaging polarimetry.
Methods. We obtained JHK-band polarimetric images using the adaptive optics instruments NACO on the VLT, and CIAO on the Subaru telescope.
Results. Our NACO JK_S-band images of $\sim$0.1$''$ angular resolution resolve clearly the R Mon binary system as well as twisted string-like features in the fan-shaped lobe. The polarimetric images reveal a butterfly-shaped polarization disk with an almost constant shape and an extension of 4$''$ in the J, H, and K bands. In this region, the polarization values are as low as $P_J \sim 7\%$, $P_H \sim 2\%$, and $P_K \sim 1\%$, and the polarization vectors are not systematically aligned along the equatorial plane. On the other hand, highly polarized scattered light is detected in the fan-shaped lobe ($P_J \sim 24\%$, $P_H \sim 33\%$, and $P_K \sim 53\%$).
Conclusions. Our polarimetric data suggests the presence of multiple grain populations in the R Mon nebula. From our one-dimensional single scattering modeling, the maximum grain size in the nebula at large scale is estimated to be 0.23 μm. On the other hand, the aforementioned properties of the polarization disk and a nearly spherical appearance of the nebulosity close to the central star suggests the presence of large grains (micron-size or larger) in the polarization disk.

Published by Astronomy and Astrophysics (Vol. 488, p. L75)

High Resolution K-band Spectroscopy of MWC 480 and V1331 Cyg

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We present high resolution (R=25,000–35,000) K-band spectroscopy of two young stars, MWC 480 and V1331 Cyg. Earlier spectrally dispersed (R=230) interferometric observations of MWC 480 indicated the presence of an excess continuum emission interior to the dust sublimation radius, with a spectral shape that was interpreted as evidence for hot water emission from the inner disk of MWC 480. Our spectrum of V1331 Cyg reveals strong emission from CO and hot water vapor, likely arising in a circumstellar disk. In comparison, our spectrum of MWC 480 appears mostly featureless. We discuss possible ways in which strong water emission from MWC 480 might go undetected in our data. If strong water emission is in fact absent from the inner disk, as our data suggest, the continuum excess interior to the dust sublimation radius that is detected in the interferometric data must have another origin. We discuss possible physical origins for the continuum excess.

Accepted by ApJ

CO Fundamental Emission from V836 Tau

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We present high resolution 4.7μm CO fundamental spectroscopy of V836 Tau, a young star with properties that are between those of classical and weak T Tauri stars and which may be dissipating its circumstellar disk. We find that the CO line profiles of V836 Tau are unusual in that they are markedly double-peaked, even after correcting for stellar photospheric absorption in the spectrum. This suggests that the CO emission arises from a restricted range of disk radii (< 0.5 AU), in contrast to the situation for most classical T Tauri stars where the CO emission extends out to much larger radii ($\sim 1 - 2$ AU). We discuss whether the outer radius of the emission in V836 Tau results from the physical truncation of the disk or an excitation effect. We also explore how either of these hypotheses may bear on our understanding of disk dissipation in this system.

Accepted by ApJ

Magnetically Regulated Star Formation in Three Dimensions: The Case of the Taurus Molecular Cloud Complex

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We carry out three-dimensional MHD simulations of star formation in turbulent, magnetized clouds, including ambipolar diffusion and feedback from protostellar outflows. The calculations focus on relatively diffuse clouds threaded by a strong magnetic field capable of resisting severe tangling by turbulent motions and retarding global gravitational contraction in the cross-field direction. They are motivated by observations of the Taurus molecular cloud complex (and, to a lesser extent, Pipe Nebula), which shows an ordered large-scale magnetic field, as well as elongated condensations that are generally perpendicular to the large-scale field. We find that stars form in earnest in such clouds when enough material has settled gravitationally along the field lines that the mass-to-flux ratios of the condensations approach the critical value. Only a small fraction (of order 1% or less) of the nearly magnetically-critical, condensed material is turned into stars per local free-fall time, however. The slow star formation takes place in condensations that are moderately supersonic; it is regulated primarily by magnetic fields, rather than turbulence. The quiescent condensations are surrounded by diffuse halos that are much more turbulent, as observed in the Taurus complex. Strong support for magnetic regulation of star formation in this complex comes from the extremely slow conversion of the already condensed, relatively quiescent $C^{18}O$ gas into stars, at a rate two orders of magnitude below the maximum, free-fall value. We analyze the properties of dense cores, including their mass spectrum, which resembles the stellar initial mass function.

Accepted by The Astrophysical Journal (vol. 686)

arXiv:0804.4201

Detection of C_3O in the Low-Mass Protostar Elias 18

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We have performed new laboratory experiments which gave us the possibility to obtain an estimate of the amount of carbon chain oxides (namely C_3O_2, C_2O, and C_3O) formed after irradiation (with 200 keV protons) of pure CO ice, at 16 K. The analysis of laboratory data indicates that in dense molecular clouds, when high CO depletion occurs, an amount of carbon chain oxides as high as (2-3) $\times 10^{-3}$ with respect to gas phase carbon monoxide can be formed after ion irradiation of icy grain mantles. Then we searched for gas phase C_2O and C_3O toward 10 low-mass young stellar objects. Among these we detected the C_3O line at 38486.891 MHz toward the low-mass protostar Elias 18. On the basis of the laboratory results we suggest that in dense molecular clouds gas phase carbon chain oxides are formed in

the solid phase after cosmic ion irradiation of CO-rich icy mantles and released to the gas phase after desorption of icy mantles. We expect that the Atacama Large Millimeter Array (ALMA), thanks to its high sensitivity and resolution, will increase the number of carbon chain oxides detected in dense molecular clouds.

Published by The Astrophysical Journal (Vol. 685, p. 1033)

Detection of 6.7 GHz methanol absorption towards hot corinos

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Methanol masers at 6.7 GHz have been found exclusively towards high-mass star forming regions. Recently, some Class 0 protostars have been found to display conditions similar to what are found in hot cores that are associated with massive star formation. These hot corino sources have densities, gas temperatures, and methanol abundances that are adequate for exciting strong 6.7 GHz maser emission. This raises the question of whether 6.7 GHz methanol masers can be found in both hot corinos and massive star forming regions, and if not, whether thermal methanol emission can be detected. We searched for the 6.7 GHz methanol line towards five hot corino sources in the Perseus region using the Arecibo radio telescope. To constrain the excitation conditions of methanol, we observed thermal submillimeter lines of methanol in the NGC1333-IRAS 4 region with the APEX telescope. We did not detect 6.7 GHz emission in any of the sources, but found absorption against the cosmic microwave background in NGC1333-IRAS 4A and NGC1333-IRAS 4B. Using a large velocity gradient analysis, we modeled the excitation of methanol over a wide range of physical parameters, and verify that the 6.7 GHz line is indeed strongly anti-inverted for densities lower than 10^6 cm^{-3}. We used the submillimeter observations of methanol to verify the predictions of our model for IRAS 4A by comparison with other CH3OH transitions. Our results indicate that the methanol observations from the APEX and Arecibo telescopes are consistent with dense (n $\sim 10^6$ cm^{-3}), cold (T $\sim$ 15-30 K) gas. The lack of maser emission in hot corinos and low-mass protostellar objects in general may be due to densities that are much higher than the quenching density in the region where the radiation field is conducive to maser pumping.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/0808.1984

Imaging galactic diffuse gas: Bright, turbulent CO surrounding the line of sight to NRAO150

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Aims: To understand the environment and extended structure of the host galactic gas whose molecular absorption line chemistry, we previously observed along the microscopic line of sight to the blazar/radiocontinuum source NRAO150 (*aka* B0355+508).

Methods: We used the IRAM 30m Telescope and Plateau de Bure Interferometer to make two series of images of the host gas: i) 22.5″ resolution single-dish maps of ^{12}CO J=1-0 and 2-1 emission over a 220″by 220″ field; ii) a hybrid (interferometer+singledish) aperture synthesis mosaic of ^{12}CO J=1-0 emission at 5.8″ resolution over a 90″-diameter region.

Results: At 22.5″ resolution, the CO J=1-0 emission toward NRAO150 is 30-100% brighter at some velocities than seen previously with 1′ resolution, and there are some modest systematic velocity gradients over the 220″ field. Of the five CO components seen in the absorption spectra, the weakest ones are absent in emission toward NRAO150 but appear more strongly at the edges of the region mapped in emission. The overall spatial variations in the strongly

emitting gas have Poisson statistics with rms fluctuations about equal to the mean emission level in the line wings and much of the line cores. The J=2-1/J=1-0 line ratios calculated pixel-by-pixel cluster around 0.7. At 6″ resolution, disparity between the absorption and emission profiles of the stronger components has been largely ameliorated. The ^{12}CO J=1-0 emission exhibits i) remarkably bright peaks, $T_{\rm mb} = 12 - 13\,{\rm K}$, even as 4″ from NRAO150; ii) smaller relative levels of spatial fluctuation in the line cores, but a very broad range of possible intensities at every velocity; and iii) striking kinematics whereby the monotonic velocity shifts and supersonically broadened lines in 22.5″ spectra are decomposed into much stronger velocity gradients and abrupt velocity reversals of intense but narrow, probably subsonic, line cores.

Conclusions: CO components that are observed in absorption at a moderate optical depth (0.5) and are undetected in emission at 1′ resolution toward NRAO 150 remain undetected at 6″ resolution. This implies that they are not a previously-hidden large-scale molecular component revealed in absorption, but they do highlight the robustness of the chemistry into regions where the density and column density are too low to produce much rotational excitation, even in CO. Bright CO lines around NRAO150 most probably reflect the variation of a chemical process, i. e. the C^+-CO conversion. However, the ultimate cause of the variations of this chemical process in such a limited field of view remains uncertain.

Accepted by Astronomy & Astrophysics

URL: astro-ph/0808.3722 or http://www.aanda.org/10.1051/0004-6361:200809803

The Peculiar Periodic YSO WL 4 in ρ Ophiuchus

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We present the discovery of 130.87 day periodic near-infrared flux variability for the Class II T Tauri star WL 4 (=2MASS J16271848-2429059, ISO-Oph 128). Our data are from the 2MASS Calibration Point Source Working Database and constitute 1580 observations in J, H, and K_S of a field in ρ Ophiuchus used to calibrate the 2MASS All-Sky Survey. We identify a light curve for WL 4 with eclipse amplitudes of ∼0.4 mag lasting more than one-quarter the period and color variations in J–H and H–K_S of ∼0.1 mag. The long period cannot be explained by stellar rotation. We propose that WL 4 is a triple YSO system, with an inner binary orbital period of 130.87 days. We posulate that we are observing each component of the inner binary alternately being eclipsed by a circumbinary disk with respect to our line of sight. This system will be useful in investigating terrestrial-zone YSO disk properties and dynamics at ∼1 Myr.

Published by The Astrophysical Journal Letters (Vol. 684, L37)

The dense ring in the Coalsack: the merging of two subsonic flows?

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A recent high angular resolution extinction map toward the most opaque molecular globule, Globule 2, in the Coalsack Nebula revealed that it contains a strong central ring of dust column density. This ring represents a region of high density and pressure that is likely a transient and possibly turbulent structure. Dynamical models suggest that the ring has formed as a result of a sudden increase in external pressure which is driving a compression wave into the Globule. Here we combine the extinction measurements with a detailed study of the $C^{18}O$ (1–0) molecular line profiles toward Globule 2 in order to investigate the overall kinematics and, in doing so, test this dynamical model. We find that the ring corresponds to an enhancement in the $C^{18}O$ non-thermal velocity dispersion and non-thermal pressure.

We observe a velocity gradient across the Globule that appears to trace two distinct systematic subsonic velocity flows that happen to converge within the ring. We suggest, therefore, that the ring has formed as two subsonic flows of turbulent gas merge within the Globule. The fact that the outer layers of the Globule appear stable against collapse yet there is no centrally condensed core, suggests that the Globule may be evolving from the outside in and has yet to stabilize, confirming its youth.

Accepted by ApJ

http://arxiv.org/abs/0809.2038

Mean motion resonances from planet-planet scattering

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Planet-planet scattering is the leading mechanism to explain the large eccentricities of the observed exoplanet population. However, scattering has not been considered important to the production of pairs of planets in mean motion resonances (MMRs). We present results from a large number of numerical simulations of dynamical instabilities in 3-planet systems. We show that MMRs arise naturally in about five percent of cases. The most common resonances we populate are the 2:1 and 3:1 MMRs, although a wide variety of MMRs can occur, including high-order MMRs (up to eleventh order). MMRs are generated preferentially in systems with uneven mass distributions: the smallest planet is typically ejected after a series of close encounters, leaving the remaining, more massive planets in resonance. The distribution of resonant planets is consistent with the phase-space density of resonant orbits, meaning that planets are randomly thrown into MMRs rather than being slowly pulled into them. It may be possible to distinguish between MMRs created by scattering vs. convergent migration in a gaseous disk by considering planetary mass ratios: resonant pairs of planets beyond ∼1 AU with more massive outer planets are likely to have formed by scattering. In addition, scattering may be responsible for pairs of planets in high-order MMRs (3:1 and higher) that are not easily populated by migration. The frequency of MMRs from scattering is comparable to the expected survival rate of MMRs in turbulent disks. Thus, planet-planet scattering is likely to be a major contributor to the population of resonant planets.

Accepted by ApJ Letters

http://arxiv.org/abs/0809.3449

Investigating the flyby scenario for the HD 141569 system

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HD 141569, a triple star system, has been intensively observed and studied for its massive debris disk. It was rather regarded as a gravitationally bound triple system but recent measurements of the HD 141569A radial velocity seem to invalidate this hypothesis. The flyby scenario has therefore to be investigated to test its compatibility with the observations. We present a study of the flyby scenario for the HD141569 system, by considering 3 variants: a sole flyby, a flyby associated with one planet and a flyby with two planets. We use analytical calculations and perform N-body numerical simulations of the flyby encounter. The binary orbit is found to be almost fixed by the observational constraint on a edge-on plane with respect to the observers. If the binary has had an influence on the disk structure, it should have a passing time at the periapsis between 5000 and 8000 years ago and a distance at periapsis between 600 and 900 AU. The best scenario for reproducing the disk morphology is a flyby with only 1 planet. For a 2 Mj (resp. 8 Mj) planet, its eccentricity must be around 0.2 (resp. below 0.1). In the two cases, its apoapsis is about 130 AU. Although the global disk shape is reasonably well reproduced, some features cannot be explained by the present model and the likehood of the flyby event remains an issue. Dynamically speaking, HD 141569 is still a puzzling system.

Accepted by Astronomy and Astrophysics

http://arxiv.org/abs/0809.4421

Evidence for a Photoevaporated Circumbinary Disk in Orion

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We have found a photoevaporated disk in the Orion Nebula that includes a wide binary. HST/ACS observations of the proplyd 124-132 show two point-like sources separated by $0.15''$, or about 60 AU at the distance of Orion. The two sources have nearly identical I and z magnitudes. We analyze the brightest component, source N, comparing the observed magnitudes with those predicted using a 1 Myr Baraffe/NEXTGEN isochrone with different accretion luminosities and extinctions. We find that a low mass ($\simeq 0.04\ M_\odot$) brown dwarf $\sim$ 1 Myr old with mass accretion rate $\log \dot{M} \simeq -10.3$, typical for objects of this mass, and about 2 magnitudes of visual extinction provides the best fit to the data. This is the first observation of a circumbinary disk undergoing photoevaporation and, if confirmed by spectroscopic observations, the first direct detection of a wide substellar pair still accreting and enshrouded in its circumbinary disk.

Accepted by Astroph. J. Letters

preprint on arXiv:0809.3208

Intrinsically Red Sources observed by *Spitzer* in the Galactic Mid-Plane

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We present a highly reliable flux-limited census of 18,949 point sources in the Galactic mid-plane that have intrinsically red mid-infrared colors. These sources were selected from the *Spitzer Space Telescope* GLIMPSE I and II surveys of $274\,\mathrm{deg}^2$ of the Galactic mid-plane, and consist mostly of high- and intermediate-mass young stellar objects (YSOs) and asymptotic giant branch (AGB) stars. The selection criteria were carefully chosen to minimize the effects of position-dependent sensitivity, saturation, and confusion. The distribution of sources on the sky and their location in IRAC and MIPS $24\,\mu$m color-magnitude and color-color space are presented. Using this large sample, we find that YSOs and AGB stars can be mostly separated by simple color-magnitude selection criteria into approximately $50-70\%$ of YSOs and $30-50\%$ of AGB stars. Planetary nebulae and background galaxies together represent at most $2-3\%$ of all the red sources. 1,004 red sources in the GLIMPSE II region, mostly AGB stars with high mass-loss rates, show significant ($\geq$0.3 mag) variability at 4.5 and/or $8.0\,\mu$m. With over 11,000 likely YSOs and over 7,000 likely AGB stars, this is to date the largest uniform census of AGB stars and high- and intermediate mass YSOs in the Milky-Way Galaxy.

Accepted by The Astronomical Journal

http://arxiv.org/abs/0809.1654

Millimeter interferometry of W3 IRS5: A Trapezium in its making

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Context: Although most young massive stars appear to be part of multiple systems, it is poorly understood how this multiplicity influences the formation of massive stars. The high-mass star-forming region W3 IRS5 is a prime example of a young massive cluster where the cluster center is resolved into multiple subsources at cm and infrared wavelengths, a potential proto-Trapezium system.
Aims: We investigate the protostellar content in the 1.4 mm continuum down to subarcsecond scales and study the compact outflow components, also tracing the outflows back to their driving sources via the shocktracing SiO and SO_2 emission.
Methods: The region W3 IRS5 was mapped with the PdBI at 1.4 mm and 3.4 mm in the AB configurations, tuning the receivers to observe the molecular transitions SO_2 ($22_{2,20}$–$22_{1,21}$), SO_2 ($8_{3,5}$–$9_{2,8}$), SiO (2–1), and SiO (5–4).
Results: In the continuum we detect five sources, one of them for the first time, while counterparts were detected in the NIR, MIR or at radio wavelengths for the remaining four sources. Three of the detected sources are within the inner 2100 AU, where the protostellar number density exceeds 10^6 protostars pc^{-3} assuming spherical symmetry. Lower limits for the circumstellar masses of the detected sources were calculated, ranging from $\sim$0.3 to $\sim$40 $M_\odot$ although they were strongly affected by the spatial filtering of the interferometer, losing up to $\sim$90% of the single-dish flux. However, the projected separations of the sources ranging between $\sim$ 750 and $\sim$ 4700 AU indicate a multiple, Trapezium-like system. We disentangled the compact outflow component of W3 IRS5, detecting five molecular outflows in SiO, two of them nearly in the line of sight direction, which allowed us to see the collapsing protostars in the NIR through the cavities carved by the outflows. The SO_2 velocity structure indicates a rotating, bound system, and we find tentative signatures of converging flows as predicted by the gravoturbulent star formation and converging flow theories.
Conclusions: The obtained data strongly indicate that the clustered environment has a major influence on the formation of high-mass stars; however, our data do not clearly allow us to distinguish whether the ongoing star-forming process follows a monolithic collapse or a competitive accretion mechanism.

Accepted by Astronomy & Astrophysics

Preprints available at `http://arxiv.org/abs/0809.0292`

Optical spectroscopy of X-ray sources in the Taurus molecular cloud: discovery of ten new pre-main sequence stars

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We have analyzed optical spectra of 25 X-ray sources identified as potential new members of the Taurus molecular cloud (TMC), in order to confirm their membership in this star forming region. Fifty-seven candidate members were previously selected among the X-ray sources in the XEST survey, having a 2MASS counterpart compatible with a pre-main sequence star based on color-magnitude and color-color diagrams. We obtained high-resolution optical spectra for 7 of these candidates with the SARG spectrograph at the TNG telescope, which were used to search for lithium absorption and to measure the Hα line and the radial and rotational velocities. Then, 18 low-resolution optical spectra obtained with the instrument DOLORES for other candidate members were used for spectral classification, for Hα measurements, and to assess membership together with IR color-color and color-magnitude diagrams and additional information from the X-ray data. We found that 3 sources show lithium absorption, with equivalent widths (EWs) of $\sim 500\,\mathrm{m\AA}$, broad spectral line profiles, indicating rotational velocities of $\sim 20-40\,\mathrm{km\,s^{-1}}$, radial velocities consistent with those for known members, and Hα emission. Two of them are classified as new weak-lined T Tauri stars, while

the EW (~ -9 Å) of the Hα line and its broad asymmetric profile clearly indicate that the third star (XEST-26-062) is a classical T Tauri star. Fourteen sources observed with DOLORES are M-type stars. Fifteen sources show Hα emission. Six of them have spectra that indicate surface gravity lower than in main sequence stars, and their dereddened positions in IR color-magnitude diagrams are consistent with their derived spectral type and with pre-main sequence models at the distance of the TMC. The K-type star XEST-11-078 is confirmed as a new member on the basis of the strength of the Hα emission line. Overall, we confirm membership to the TMC for 10 out of 25 X-ray sources observed in the optical. Three sources remain uncertain.

Accepted by Astronomy & Astrophysics

http://www.astropa.unipa.it/Library/preprint.html

The Nature of the Soft X-ray Source in DG Tauri

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The classical T Tauri star DG Tau shows all typical signatures of X-ray activity and, in particular, harbors a resolved X-ray jet. DG Tau's jet is one of the most well studied jets of young stellar objects, having been observed for more than 25 years by a variety of instruments. We demonstrate that its soft and hard X-ray components are separated spatially by approximately 0.2 arcsec by deriving the spatial offset between both components from the event centroids of the soft and hard photons utilizing the intrinsic energy-resolution of the Chandra ACIS-S detector. We also demonstrate that this offset is physical and cannot be attributed to an instrumental origin or to low counting statistics. Furthermore, the location of the derived soft X-ray emission peak coincides with emission peaks observed for optical emission lines, suggesting that both soft X-rays and optical emission have the same physical origin.

Published by Astronomy and Astrophysics (Vol. 488, p. L13)

Chemistry in Disks. II. – Poor molecular content of the AB Aur disk.

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We study the molecular content and chemistry of a circumstellar disk surrounding the Herbig Ae star AB Aur at (sub-)millimeter wavelengths. Our aim is to reconstruct the chemical history and composition of the AB Aur disk and to compare it with disks around low-mass, cooler T Tauri stars. We observe the AB Aur disk with the IRAM Plateau de Bure Interferometer in the C- and D- configurations in rotational lines of CS, HCN, C_2H, CH_3OH, HCO^+, and CO isotopes. Using an iterative minimization technique, observed columns densities and abundances are derived. These values are further compared with results of an advanced chemical model that is based on a steady-state flared disk structure with a vertical temperature gradient, and gas-grain chemical network with surface reactions. We firmly detect HCO^+ in the 1–0 transition, tentatively detect HCN, and do not detect CS, C_2H, and CH_3OH. The observed HCO^+ and ^{13}CO column densities as well as the upper limits to the column densities of HCN, CS, C_2H, and CH_3OH are in good agreement with modeling results and those from previous studies. The AB Aur disk possesses more CO, but is less abundant in other molecular species compared to the DM Tau disk. This is primarily caused by intense UV irradiation from the central Herbig A0 star, which results in a hotter disk where CO freeze out does not occur and thus surface formation of complex CO-bearing molecules might be inhibited.

Accepted by A&A

arXiv:0809.3473

A Large-Area Search for Low-Mass Objects in Upper Scorpius II: Age and Mass Distributions

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We present continued results from a wide-field, ∼150 deg^2, optical photometric and spectroscopic survey of the northern part of the ∼5 Myr-old Upper Scorpius OB Association. Photometry and spectral types were used to derive effective temperatures and luminosities and place newly identified association members onto a theoretical Hertzsprung-Russell diagram. From our survey, we have discovered 145 new low mass members of the association, and determined ∼10% of these objects to be actively accreting material from a surrounding circumstellar disk. Based on comparison of the spatial distributions of low and high mass association members, we find no evidence for spatial segregation by mass within the northern portion of the association. Measured data are combined with pre-main sequence evolutionary models to derive a mass and age for each star. Using Monte Carlo simulations we show that, taking into account known observational uncertainties, the observed age dispersion for the low mass population in USco is consistent with all stars forming in a single burst ∼5 Myr ago, and place an upper limit of ±3 Myr on the age spread if the star formation rate has been constant in time. We derive the first spectroscopic mass function for USco that extends into the substellar regime, and compare these results to those for three other young clusters and associations.

Accepted by the Astrophysical Journal

Dynamical Masses for the Large Magellanic Cloud Massive Binary System [L72] LH 54-425

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We present results from an optical spectroscopic investigation of the massive binary system [L72] LH 54-425 in the LH 54 OB association in the Large Magellanic Cloud. We revise the ephemeris of [L72] LH 54-425 and find an orbital period of 2.24741 ± 0.00004 days. We find spectral types of O3 V for the primary and O5 V for the secondary. We made a combined solution of the radial velocities and previously published V-band photometry to determine the inclination for two system configurations, $i = 52^{+2}_{-3}$ degrees for the configuration of the secondary star being more tidally distorted and $i = 55° \pm 1°$ for the primary as the more tidally distorted star. We argue that the latter case is more probable, and this solution yields masses and radii of $M_i = 47 \pm 2\ M_\odot$ and $R_2 = 11.4 \pm 0.1\ R_\odot$ for the primary, and $M_2 = 28 \pm 1\ M_\odot$ and $R_2 = 8.1 \pm 0.1\ R_\odot$ for the secondary. Our analysis places LH 54-425 among the most massive stars known. Based on the position of the two stars plotted on a theoretical HR diagram, we find the age of the system to be ∼1.5 Myr.

Published by The Astrophysical Journal (Vol. 682, p. 492)

Long-Wavelength Excesses of FU Orionis Objects: Flared Outer Disks or Infalling Envelopes?

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The mid- to far-infrared emission of the outbursting FU Orionis objects has been attributed either to a flared outer disk or to an infalling envelope. We revisit this issue using detailed radiative transfer calculations to model the recent, high signal-to-noise ratio data from the IRS instrument on the *Spitzer Space Telescope*. In the case of FU Ori, we find that a physically plausible flared disk irradiated by the central accretion disk matches the observations. Building on our previous work, our accretion disk model with outer disk irradiation by the inner disk reproduces the spectral energy distribution between ∼4000 Å and ∼40 μm. Our model is consistent with near-infrared interferometry, but there are some inconsistencies with mid-infrared interferometric results. Including the outer disk allows us to refine our estimate of the outer radius of the outbursting, high mass accretion rate disk in FU Ori as ∼0.5 AU, which is a crucial parameter in assessing theories of the FU Orionis phenomenon. We are able to place an upper limit on the mass infall rate of any remnant envelope infall rate to $\sim 7 \times 10^{-7}\ M_\odot\ \mathrm{yr}^{-1}$ assuming a centrifugal radius of 200 AU. The FUor BBW 76 is also well modeled by a 0.6 AU inner disk and a flared outer disk. However, V1515 Cyg requires an envelope with an outflow cavity to adequately reproduce the IRS spectrum. In contrast with the suggestion by Green et al., we do not require a flattened envelope to match the observations; the inferred cavity shape is qualitatively consistent with typical protostellar envelopes. This variety of dusty structures suggests that the FU Orionis phase can be present at either early or late stages of protostellar evolution.

Published by The Astrophysical Journal (Vol. 684, 1281)

A representative particle approach to coagulation and fragmentation of dust aggregates and fluid droplets

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Context: There is increasing need for good algorithms for modeling the aggregation and fragmentation of solid particles (dust grains, dust aggregates, boulders) in various astrophysical settings, including protoplanetary disks, planetary- and sub-stellar atmospheres and dense molecular cloud cores. Here we describe a new algorithm that combines advantages of various standard methods into one.

Aims: The aim is to develop a method that 1) can solve for aggregation and fragmentation, 2) can easily include the effect and evolution of grain properties such as compactness, composition, etc., and 3) can be built as a coagulation/fragmentation module into a hydrodynamics simulations.

Methods: We develop a Monte-Carlo method in which we follow the 'life' of a limited number of representative particles. Each of these particles is associated with a certain fraction of the total dust mass and thereby represents a large number of true particles which all are assumed to have the same properties as their representative particle. Under the assumption that the total number of true particles vastly exceeds the number of representative particles, the chance of a representative particle colliding with another representative particle is negligibly small, and we therefore ignore this possibility. This now makes it possible to employ a statistical approach to the evolution of the representative particles.

Results: The method reproduces the known analytic solutions of simplified coagulation kernels, and compares well to numerical results for Brownian motion using other methods. For reasonably well-behaved kernels it produces good results even for moderate number of swarms.

Accepted by A&A

http://arxiv.org/abs/0807.5052

Survey of Young Stars: Binarity and Variability

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Ph.D dissertation directed by: Luiz Paulo Ribeiro Vaz and Bo Reipurth

Ph.D degree awarded: September 2008

In the attempt of increasing our knowledge about young stars, we performed three large scale surveys of two star forming regions, namely the Orion Nebula and the young OB association known as Cygnus OB2.

The first survey was made with the Advanced Camera for Surveys (ACS) onboard the Hubble Space Telescope. We used a narrow band filter, centered in the wavelength of the Hα line, to map the region around the center of the Orion Nebula Cluster. Our main goal is to use the high resolution of the ACS ($0.05''$ per pixel) to detect new visual binaries. We set the separation limit between the components of the system ($0.15''$ to $1.5''$) using completeness tests and the probability of chance alignment. After a minute analysis of each system detected in our sample, we reached our goal and also observed clear evidence of the dynamical evolution of these systems in the Orion Nebula Cluster. We discovered 55 new visual binary systems within a total of 72 binaries and 3 triple systems. We determined a binary frequency of $(8.8\pm1.1)\%$ for the Orion Nebula Cluster, which is 1.5 times smaller than the frequency for the field and 2.2 times smaller than for the loose T associations. This was an already known fact but was based on small number statistics, while our results are based on more significant numbers. The ratio between wide and close binaries has a significant increase at $460''$ from the center of the cluster, assumed to be the star θ^1 Ori C . Our analysis indicates that this is clear evidence of the dynamical evolution of the Orion Nebula Cluster, which happens through the destruction of wide binaries, after few passages through the cluster's potential well. A byproduct of our survey is the detection of substellar candidates. We determined the double nature of the object known as COUP1061, which is classified in the literature as a brown dwarf. This finding implies that COUP1061 is a binary system where both components are brown dwarfs, separated by $\sim$100 AU.

In order to perform the second and third surveys we made use of the Wide Field Camera of the United Kingdom Infrared Telescope. We observed the Orion Nebula and Cygnus OB2 with near infrared filters, JHK. Our objective with these photometric surveys is to determine the population of variable stars in these star forming regions. Using statistical indices we can separate and classify the variable stars into different groups. Because these photometric surveys cover large areas in the sky we developed special routines to deal with the catalogs, which are composed of thousands and sometimes hundreds of thousands of objects.

The Orion Nebula was observed during 101 nights. Long cataloging and calibration processes were necessary until a satisfying dataset was ready to be used in the search for variable stars. Using statistical indices we were able to classify the objects in many differents groups. We discovered new eclipsing binary candidates and also variability due to rotation and/or pulsation.

A preliminary analysis of the Cygnus OB2 data allowed us to discover 6 small scale cometary globules. This finding is strong evidence of the recent star formation process that occurred in this region. We also detected 4 infrared sources, apparently young and possibly located in the Perseus Arm, far more distant than the Cygnus OB2 association. We also determined the double nature of the IRAS 20304+4059 infrared source, which is classified as a protostar.

Postdoctoral position in star formation and molecular cloud physics

The Yale University Astronomy Department invites applications for a post-doctoral research position in observational star formation and molecular cloud physics. The successful applicant will collaborate with Prof. Hector Arce on studies of star forming regions using millimeter, sub-millimeter and infrared data as well as radiative transfer codes. The postdoctoral associate will also have time to perform his or her own research. The initial appointment is for two years, renewable for a third, and offers competitive salary and benefits, and travel and research funds. Candidates must hold a Ph.D. in astronomy or related field by date of appointment. The applicant should have experience in observations of star-forming regions at centimeter, millimeter, submillimeter, and/or infrared wavelengths. Experience with radio interferometer observations is desirable.

Conveniently located between New York City and Boston, Yale University offers a world-class intellectual environment and access to front-line astronomical facilities, including the WIYN, the SMARTS telescopes, astronomical facilities in Chile (through collaboration with the Universidad de Chile), and the Palomar-QUEST survey.

Applications consisting of a cover letter, curriculum vitae, publication list, and a brief (2-3 page) description of research interests and plans should arrive by December 1, 2008. Applicants should also arrange for three letters of recommendation to arrive by the same date. Email all materials, including letters, to susan.delong@yale.edu. Yale University is an Affirmative Action/Equal Opportunity Employer, and we particularly encourage applications from women and members of minority groups.

Star and Planet Formation Research, ETH, Zurich

The Institute of Astronomy of the Swiss Federal Institute of Technology (ETH Zurich) is establishing a new research group in star and planet formation. The focus of the research group will be in the areas of: (i) star clusters and the origin of the initial mass function; (ii) formation and evolution of planetary systems; and (iii) ground- and space-based optical/infrared instrumentation.

Applications are invited for several new positions at a variety of levels including graduate studentships, postdoctoral fellows, as well as more senior levels. Applicants with a particular interest in science education will also be considered. Salaries and duration of appointments will be commensurate with experience. For example, starting salaries for new PhDs begin at CHF 78'000, with initial appointments of 2+1 years, up to a maximum of six years. Advanced candidates will have opportunities to work with students at all levels.

Switzerland is a member of ESO and ESA, and successful applicants will have full access to their facilities, as well as data from ongoing programs utilizing the Hubble Space Telescope, and the Spitzer Space Telescope. The Institute of Astronomy maintains a network of workstations and a large fast-connection Beowulf cluster and has competitive access to the Cray XT, IBM and other supercomputers of the Swiss National Supercomputing Center (CSCS). Members of the Institute also play a leading role in the interdisciplinary PLANET-Z initiative linking research groups at the ETH Zurich, the University of Zurich, and the University of Bern. Interested applicants will have an opportunity to participate in setting up a new infrared instrumentation laboratory.

Applications are invited from all nationalities and should consist of a CV, publication list, and brief descriptions of past and proposed research (combined length not to exceed 10 pages) . Materials should be sent electronically in a single pdf file. This file, as well as three letters of reference (sent directly by the referees) should be sent to eth-astro-star-planet@phys.ethz.ch. Review of applications will begin December 1, 2008.

For more information concerning the new ETH Star and Planet Formation Research Group, visit
http://www.astro.phys.ethz.ch or contact Professor Michael R. Meyer at mmeyer@phys.ethz.ch.

CONSTELLATION SCHOOL ON NUMERICAL ASTROPHYSICS AND ITS ROLE IN STAR FORMATION

2009 January 19-23, Cardiff University, UK

http://www.astro.cf.ac.uk/groups/starform/school2009/

Numerical simulations play an increasingly important role in the study of star formation, both as a means of interpreting observations (which may be poorly resolved, confused, or optically thick), and as a means of time-sequencing observations of star formation regions in diffeent stages of development. This school is intended to be an introduction to the techniques of numerical astrophysics, and their application to problems in star formation. It is aimed at postgrads and postdocs working in the field, includng those whose main activity is in observaton. The areas to be covered are: *N-body Dynamics*, *Radiation Transport*, *The Energy Equation and Chemistry*, *Smoothed Particle Hydrodynamics*, *Finite Difference Hydrodynamics*, *Early Stellar Evolution*.

PROGRAMME. A detailed schedule of talks, confirmed speakers, posters, and – as available – abstracts, can be found at the conference website (see above).

CONTRIBUTIONS. Contributed talks and/or posters are welcome.

REGISTRATION. There are limited numbers of places and talk-slots, so early registration (via the conference website) is encouraged.

ACCOMMODATION. Participants should arrange their own accommodation.

PROCEEDINGS. The talks and posters will be posted online.

The school is part of a programme of meetings organised by the Marie Curie Research Training Network CONSTELLATION, funded by the European Commission under contract MRTN-CT-2006-035890.

SOC: Matthew Bate, Ian Bonnell, Gilles Chabrier, Ralf Klessen, Mordecai Mac Low, Richard Nelson, Francesco Palla, Jan Palous, Ken Rice, Ant Whitworth (chair).

LOC: Annabel Cartwright, Katharina Jappsen, Dimitri Stamatellos, Derek Ward-Thompson, Steffi Walch, Ant Whitworth, Richard Wünsch.