THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 174 — 22 April 2007 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

Abstracts of recently accepted papers

The H II Region of a Primordial Star

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The concordance model of cosmology and structure formation predicts the formation of isolated, very massive stars at high redshifts in dark matter-dominated halos of $10^5 - 10^6$ $M_\odot$. These stars photoionize their host primordial molecular clouds, expelling all the baryons from their halos. When the stars die, a relic H II region is formed within which large amounts of molecular hydrogen form that will allow the gas to cool efficiently when gravity assembles it into larger dark matter halos. The filaments surrounding the first star-hosting halo are largely shielded and provide the pathway for gas to stream into the halo when the star has died. We present the first fully three-dimensional cosmological radiation hydrodynamical simulations that follow all these effects. A novel adaptive ray-casting technique incorporates the time-dependent radiative transfer around point sources. This approach is fast enough so that radiation transport, kinetic rate equations, and hydrodynamics are solved self-consistently. It retains the time derivative of the transfer equation and is explicitly photon-conserving. This method is integrated with the cosmological adaptive mesh refinement code Enzo and runs on distributed and shared memory parallel architectures. Where applicable, the three-dimensional calculation not only confirms expectations from earlier one-dimensional results but also illustrates the multifold hydrodynamic complexities of H II regions. In the absence of stellar winds, the circumstellar environments of the first supernovae and putative early gamma-ray bursts will be of low density, ~ 1 cm^{-3}. Albeit marginally resolved, ionization front instabilities lead to cometary- and elephant trunklike small-scale structures reminiscent of nearby star-forming regions.

Published by The Astrophysical Journal Letters (Vol. 659, p. L87)

Calibration of the pre-main sequence RS Chamaeleontis binary system

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Context. The calibration of binary systems with accurately known masses and/or radii provides powerful tools to test stellar structure and evolution theory and to determine the age and helium content of stars. We study the eclipsing double-lined spectroscopic binary system RS Cha, for which we have accurate observations of the parameters of both stars (masses, radii, luminosities, effective temperatures and metallicity).

Aims. We have calculated several sets of stellar models for the components of the RS Cha system, with the aim of reproducing simultaneously the available observational constraints and to estimate the age and initial helium abundance of the system.

Methods. Using the CESAM stellar evolution code, we model both components starting from the initial mass and metallicity and adjusting the input parameters and physics in order to satisfy the observational constraints.

Results. We find that the observations cannot be reproduced if we assume that the abundance ratios are solar but they are satisfied if carbon and nitrogen are depleted in the RS Cha system with respect to the Sun. This is in accordance with the abundances observed in other young stars. The RS Cha system is in an evolutionary stage at the end of the PMS phase where models are not strongly sensitive to various physical uncertainties. However we show that the oscillations of these two stars, which have been detected, would be able to discriminate between different options in the physical description of this evolutionary phase.

Published by Astronomy & Astrophysics (Vol. 465, p. 241)

An accurate determination of the distance to the Pipe nebula

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Aims. To obtain an accurate distance to the Pipe nebula.
Methods. B-band CCD imaging linear polarimetry collected for stars from the *Hipparcos* catalogue is used to investigate the dependence of the measured interstellar polarization as a function of the stellar's trigonometric parallax.
Results. The linear polarization obtained for 82 *Hipparcos* stars in the general direction of the Pipe nebula are presented and analysed. The distribution of the obtained position angles suggests the existence of two polarizing components. One of them has low average column density and seems to be closer than ∼70 pc from the sun, while the other component has higher column density, and seems to belong to a very extended interstellar structure. The obtained parallax–polarization diagram indicates small degree of polarization for stars with $\pi_H > 8$ mas, while a steep rise in polarization is observed for stars with $\pi_H \approx 7$ mas, corresponding to a distance of approximately 140 pc.
Conclusions. Our analysis suggests a distance of 145±16 pc to de Pipe nebula, meaning that this cloud is part of the Ophiuchus dark cloud complex. There is evidence that the largest filament of the Pipe nebula has collapsed along the magnetic field lines, indicating that magnetic pressure plays an important role in the evolution of this cloud.

Accepted by A&A

Giant collisions involving young Jupiter

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We present high-resolution, three-dimensional simulations using a smooth particle hydrodynamics (SPH) code of giant impacts involving young Jupiter-like planets. Our aim is to explore the effect of such impacts on the structure and evolution of the planet and discuss the likelihood of detecting these post-impact planets. For this, we considered head-on and off-axis impacts by an Earth-like planet onto a young Jupiter at five different ages: 1 Myr, 10 Myr, 30 Myr, 100 Myr, and 1 Gyr. We briefly discuss the short-term post-impact evolution and concentrate on computing the long-term cooling of the planet. We find that the bright IR afterglow lasts for about 10^6 yr if the impact involves a 1 Myr old planet and up to 10^8 yr if the impact occurs on an older planet (∼ 30 Myr). We estimate that, about 10 to 100 young planetary systems must be observed to detect one candidate for such post-impact object. Given that their luminosity is only increased by a roughly 50%, this frequency does not make them ideal observing targets. We note nevertheless that the detection of this kind of post giant-impact planet would represent an important milestone in observationally establishing the current planet formation theories that are based on collisions.

Published by The Astronomy & Astrophysics (Vol. 466, p. 717)

Discovery of the Widest Very Low Mass Binary

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We report the discovery of a very low mass binary system (primary mass $< 0.1\ M_\odot$) with a projected separation of $\sim$5100 AU, more than twice that of the widest previously known system. A spectrum covering the 1-2.5μm wavelength interval at R $\sim$ 1700 is presented for each component. Analysis of the spectra indicates spectral types of M6.5 V and M8 V, and the photometric distance of the system is $\sim$62 pc. Given that previous studies have established that no more than 1% of very low mass binary systems have orbits larger than 20 AU, the existence of such a wide system has a bearing on very low mass star formation and evolution models.

Published by The Astrophysical Journal Letters (Vol. 659, p. L49)

Apsidal Behavior among Planetary Orbits: Testing the Planet-Planet Scattering Model

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Planets in extrasolar systems tend to interact such that their orbits lie near a boundary between apsidal libration and circulation, a "separatrix," with one eccentricity periodically reaching near zero. One explanation, applied to the υ And system, assumed three original planets on circular orbits. One is ejected, leaving the other two with near-separatrix behavior. We test that model by integrating hundreds of hypothetical, unstable planetary systems that eject a planet. We find that the probability that the remaining planets exhibit near-separatrix motion is small (<5% compared with nearly 50% of observed systems). Moreover, while observed librating systems are evenly divided between aligned and antialigned pericenter longitudes, the scattering model strongly favors alignment. Alternative scattering theories are proposed, which may provide a more satisfactory fit with observed systems.

Published by The Astrophysical Journal Letters (Vol. 659, p. L53)

The young, wide and very low mass visual binary LOri167

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We look for wide, faint companions around members of the 5 Myr Lambda Orionis open cluster. We used optical, near-infrared, and Spitzer/IRAC photometry. We report the discovery of a very wide very low mass visual binary, LOri167, formed by a brown dwarf and a planetary-mass candidate located at 5 arcsec, which seems to belong to the cluster. We derive Teff of 2125 and 1750 K. If they are members, comparisons with theoretical models indicate masses of 17 (20-15) Mjup and 8 (13-7) Mjup, with a projected separation of 2000 AU. Such a binary system would be difficult to explain in most models, particularly those where substellar objects form in the disks surrounding higher mass stars.

Accepted by Astronomy and Astrophysics Letters

http://xxx.unizar.es/abs/0704.2469

SPITZER: Accretion in Low Mass Stars and Brown Dwarfs in the Lambda Orionis Cluster

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We present multi-wavelength optical and infrared photometry of 170 previously known low mass stars and brown dwarfs of the 5 Myr Collinder 69 cluster (Lambda Orionis). The new photometry supports cluster membership for most of them, with less than 15% of the previous candidates identified as probable non-members. The near infrared photometry allows us to identify stars with IR excesses, and we find that the Class II population is very large, around 25% for stars (in the spectral range M0 - M6.5) and 40% for brown dwarfs, despite the fact that the Hα equivalent width is low for a significant fraction of them. In addition, there are a number of substellar objects, classified as Class III, that have optically thin disks. The Class II members are distributed in an inhomogeneous way, lying preferentially in a filament running toward the south-east. The IR excesses for the Collinder 69 members range from pure Class II (flat or nearly flat spectra longward of 1 μm), to transition disks with no near-IR excess but excesses beginning within the IRAC wavelength range, to two stars with excess only detected at 24 μm. Collinder 69 thus appears to be at an age where it provides a natural laboratory for the study of primordial disks and their dissipation.

Accepted by ApJ

http://xxx.unizar.es/abs/0704.1963

Dust and gas emission in the prototypical hot core G29.96−0.02 at sub-arcsecond resolution

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Context: Hot molecular cores are an early manifestation of massive star formation where the molecular gas is heated to temperatures > 100 K undergoing a complex chemistry.
Aims: One wants to better understand the physical and chemical processes in this early evolutionary stage.
Methods: We selected the prototypical hot molecular core G29.96−0.02 being located at the head of the associated ultracompact HII region. The 862 μm submm continuum and spectral line data were obtained with the Submillimeter Array (SMA) at sub-arcsecond spatial resolution.
Results: The SMA resolved the hot molecular core into six submm continuum sources with the finest spatial resolution of $0.36'' \times 0.25''$ ($\sim$1800 AU) achieved so far. Four of them located within 7800 (AU)^2 comprise a proto-Trapezium system with estimated protostellar densities of 1.4×10^5 protostars/pc^3. The plethora of $\sim$ 80 spectral lines allows us to study the molecular outflow(s), the core kinematics, the temperature structure of the region as well as chemical effects. The derived hot core temperatures are of the order 300 K. We find interesting chemical spatial differentiations, e.g., $C^{34}S$ is deficient toward the hot core and is enhanced at the UCHII/ hot core interface, which may be explained by temperature sensitive desorption from grains and following gas phase chemistry. The SiO(8–7) emission outlines likely two molecular outflows emanating from this hot core region. Emission from most other molecules peaks centrally on the hot core and is not dominated by any individual submm peak. Potential reasons for that are discussed. A few spectral lines that are associated with the main submm continuum source, show a velocity gradient perpendicular to the large-scale outflow. Since this velocity structure comprises three of the central protostellar sources, this is not a Keplerian disk. While the data are consistent with a gas core that may rotate and/or collapse, we cannot exclude the outflow(s) and/or nearby expanding UCHII region as possible alternative causes of this velocity pattern.

Accepted by Astronomy and Astrophysics

http://www.mpia.de/homes/beuther/papers.html

Testing Disk Instability Models for Giant Planet Formation

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Disk instability is an attractive yet controversial means for the rapid formation of giant planets in our solar system and elsewhere. Recent concerns regarding the first adiabatic exponent of molecular hydrogen gas are addressed and shown not to lead to spurious clump formation in the author's disk instability models. A number of disk instability models have been calculated in order to further test the robustness of the mechanism, exploring the effects of changing the pressure equation of state, the vertical temperature profile, and other parameters affecting the temperature distribution. Possible reasons for differences in results obtained by other workers are discussed. Disk instability remains as a plausible formation mechanism for giant planets.

Accepted by Astrophys. J. Letters

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

Survival of the mm-cm size grain population observed in protoplanetary disks

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Millimeter interferometry provides evidence for the presence of mm to cm size 'pebbles' in the outer parts of disks around pre-main-sequence stars. The observations suggest that large grains are produced relatively early in disk evolution (< 1 Myr) and remain at large radii for longer periods of time (5 to 10 Myr). Simple theoretical estimates of the radial drift time of solid particles, however, imply that they would drift inward over a time scale of less than 0.1 Myr. In this paper, we address this conflict between theory and observation, using more detailed theoretical models, including the effects of sedimentation, collective drag forces and turbulent viscosity. We find that, although these effects slow down the radial drift of the dust particles, this reduction is not sufficient to explain the observationally determined long survival time of mm/cm-sized grains in protoplanetary disks. However, if for some reason the gas to dust ratio in the disk is reduced by at least a factor of 20 from the canonical value of 100 (for instance through photoevaporation of the gas), then the radial drift time scales become sufficiently large to be in agreement with observations.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/0704.2332

Arcsecond Scale Kinematic and Chemical Complexity in Cepheus A-East

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We present results from Submillimeter Array (SMA) observations of the star forming region Cepheus A-East at $\sim$340 GHz (875 μm) with $0.7'' - 2''$ resolution. At least four compact submillimeter continuum sources have been detected, as well as a rich forest of hot core line emission. Two kinematically, chemically, and thermally distinct regions of molecular emission are present in the vicinity of the HW2 thermal jet, both spatially distinct from the submillimeter counterpart to HW2. We propose that this emission is indicative of multiple protostars rather than a massive disk as reported by Patel et al. (2005).

Accepted by The Astrophysical Journal Letters

http://arxiv.org/abs/astro-ph/0703626

Discovery of Interstellar Heavy Water

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We report the discovery of doubly deuterated water (D_2O, heavy water) in the interstellar medium. Using the James Clerk Maxwell Telescope and the Caltech Submillimeter Observatory 10 m telescope, we detected the 1_{10}-1_{01} transition of para-D_2O at 316.7998 GHz in both absorption and emission toward the protostellar binary system IRAS 16293-2422. Assuming that the D_2O exists primarily in the warm regions where water ices have been evaporated (i.e., in a "hot corino" environment), we determine a total column density of $N(D_2O)$ of 1.0 $\times 10^{13}$ cm^{-2} and a fractional abundance of D_2O/H_2 = 1.7 $\times 10^{-10}$. The derived column density ratios for IRAS 16293-2422 are D_2O/HDO = 1.7 $\times 10^{-3}$ and D_2O/H_2O = 5 $\times 10^{-5}$ for the hot corino gas. Steady state models of water ice formation, either in the gas phase or on grains, predict D_2O/HDO ratios that are about 4 times larger than that derived from our observations. For water formation on grain surfaces to be a viable explanation, a larger H_2O abundance than that measured in IRAS 16293-2422 is required. Alternatively, the observed D_2O/HDO ratio could be indicative of gas-phase water chemistry prior to a chemical steady state being attained, such as would have occurred during the formation of this source. Future observations with the Herschel Space Observatory satellite will be important for settling this issue.

Published by The Astrophysical Journal Letters (Vol. 659, p. L137)

PdBI sub-arcsecond study of the SiO microjet in HH212: Origin and collimation of Class 0 jets

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Context: The bipolar HH 212 outflow has been mapped in SiO using the extended configuration of the Plateau de Bure Interferometer (PdBI), revealing a highly collimated SiO jet closely associated with the H_2 jet component. *Aims:* We study at unprecedented resolution (0.34″ across the jet axis) the properties of the innermost SiO "microjet" within 1000 AU of this young Class 0 source, to compare it with atomic microjets from more evolved sources and to constrain its origin. *Methods:* The SiO channel maps are used to investigate the microjet collimation and velocity structure. A large velocity gradient analysis is applied to SiO (2–1), (5–4) and (8–7) data from the PdBI and the Submillimeter Array to constrain the SiO opacity and abundance. *Results:* The HH212 Class 0 microjet shows striking similarities in collimation and energetic budget with atomic microjets from T Tauri sources. Furthermore, the SiO lines appear optically thick, unlike what is generally assumed. We infer $T_k \simeq$ 50–500 K and an SiO/H_2 abundance $\geq 4 \times 10^{-8} - 6 \times 10^{-5}$ for $n(H_2) = 10^7 - 10^5$cm^{-3}, i.e. $0.05 - 90\%$ of the elemental silicon. *Conclusions:* This similar jet width, regardless of the presence of a dense envelope, definitely rules out jet collimation by external pressure, and favors a common MHD self-collimation (and possibly acceleration) process at all stages of star formation. We propose that the more abundant SiO in Class 0 jets could mainly result from rapid ($\leq$ 25 yrs) molecular synthesis at high jet densities.

Accepted by A&A Letters

http://aramis.obspm.fr/∼cabrit/

Star Formation in the Bok Globule CB54

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We present mid-infrared (10.4 μm, 11.7 μm, and 18.3 μm) imaging intended to locate and characterize the suspected protostellar components within the Bok globule CB54. We detect and confirm the protostellar status for the near-infrared source CB54YC1-II. The mid-infrared luminosity for CB54YC1-II was found to be $L_{midir} \approx 8L_{\odot}$, and we estimate a central source mass of $M_* \approx 0.8M_{\odot}$ (for a mass accretion rate of $\dot{M} = 10^{-6}M_{\odot}yr^{-1}$). CB54 harbors another near-infrared source (CB54YC1-I), which was not detected by our observations. The non-detection is consistent with CB54YC1-I being a highly extinguished embedded young A or B star or a background G or F giant. An alternative explanation for CB54YC1-I is that the source is an embedded protostar viewed at an extremely high inclination angle, and the near-infrared detections are not of the central protostar, but of light scattered by the accretion disk into our line of sight. In addition, we have discovered three new mid-infrared sources, which are spatially coincident with the previously known dense core in CB54. The source temperatures ($\sim$ 100K) and association of the mid-infrared sources with the dense core suggests that these mid-infrared objects may be embedded class 0 protostars.

Accepted by The Astrophysical Journal

http://arxiv.org/abs/0704.0428

A very massive runaway star from Cygnus OB2

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Aims: We investigate the star BD+43° 3654 and the possibility that it may have originated in the massive OB association Cygnus OB2.

Methods: We present new spectroscopic observations allowing a reliable spectral classification of the star, and discuss existing MSX observations of its associated bow shock and astrometric information not previously studied.

Results: Our observations reveal that BD+43° 3654 is a very early and luminous star of spectral type O4If, with an estimated mass of (70 ± 15) M$_{\odot}$ and an age of $\sim$ 1.6 Myr. The high spatial resolution of the MSX observations allows us to determine its direction of motion in the plane of the sky by means of the symmetry axis of the well-defined bow shock, which matches well the orientation expected from the proper motion. Tracing back its path across the sky we find that BD+43° 3654 was located near the central, densest region of Cygnus OB2 at a time in the past similar to its estimated age.

Conclusions: BD+43° 3654 turns out to be one of the three most massive runaway stars known, and it most likely formed in the central region of Cygnus OB2. A runaway formation mechanism by means of dynamical ejection is consistent with our results.

Accepted by Astronomy and Astrophysics

`http://www.eso.org/∼fcomeron/cygob2_runaway.pdf`

High-resolution study of a star-forming cluster in the Cep-A HW2 region

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Due to its relatively small distance (725 pc), the Cepheus A East star-forming region is an ideal laboratory to study massive star formation processes. Based on its morphology, it has been suggested that the flattened molecular gas distribution around the YSO HW2 may be a 350-AU-radius massive protostellar disk. Goal of our work is to ascertain the nature of this structure. We have employed the Plateau de Bure Interferometer to acquire (sub-)arcsecond-resolution imaging of high-density and shock tracers, such as methyl cyanide (CH_3CN) and silicon monoxide (SiO), towards the HW2 position. On the $1''$ ($\sim$ 725 AU) scale, the flattened distribution of molecular gas around HW2 appears to be due to the projected superposition, on the plane of the sky, of at least three protostellar objects, of which at least one is powering a molecular outflow at a small angle with respect to the line of sight. The presence of a protostellar disk around HW2 is not ruled out, but such structure is likely to be detected on a smaller spatial scale, or using different molecular tracers.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/0704.1617v1

Evidence for a Massive Protocluster in S255N

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S255N is a luminous far-infrared source that contains many indications of active star formation but lacks a prominent near-infrared stellar cluster. We present mid-infrared through radio observations aimed at exploring the evolutionary state of this region. Our observations include 1.3 mm continuum and spectral line data from the Submillimeter Array (SMA), VLA 3.6 cm continuum and 1.3 cm water maser data, and multicolor IRAC images from the Spitzer Space Telescope. The cometary morphology of the previously-known UCHII region G192.584−0.041 is clearly revealed in our sensitive, multi-configuration 3.6 cm images. The 1.3 mm continuum emission has been resolved into three compact cores, all of which are dominated by dust emission and have radii < 7000 AU. The mass estimates for these cores range from 6 to 35 $M_\odot$. The centroid of the brightest dust core (SMA1) is offset by 1.1 arcsec (2800 AU) from the peak of the cometary UCHII region and exhibits the strongest HC_3N, CN, and DCN line emission in the region. SMA1 also exhibits compact CH_3OH, SiO, and H_2CO emission and likely contains a young hot core. We find spatial and kinematic evidence that SMA1 may contain further multiplicity, with one of the components coincident with a newly-detected H_2O maser. There are no mid-infrared point source counterparts to any of the dust cores, further suggesting an early evolutionary phase for these objects. The dominant mid-infrared emission is a diffuse, broadband component that traces the surface of the cometary UCHII region but is obscured by foreground material on its southern edge. An additional 4.5 micron linear feature emanating to the northeast of SMA1 is aligned with a cluster of methanol masers and likely traces an outflow from a protostar within SMA1. Our observations provide direct evidence that S255N is forming a cluster of intermediate to high-mass stars.

Accepted by The Astronomical Journal

http://arxiv.org/abs/0704.0988 (full resolution version = http://www.gb.nrao.edu/~thunter/papers/ms_S255_final.pdf)

Statistical analysis of molecular line emission from T Tauri disk models

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In this work we model the expected emission from the molecular line $C^{17}O(J=3 \rightarrow 2)$ in protoplanetary disks, modifying different physical parameters to obtain distinctive observational signatures. Our aim is to determine the kind of observations that will allow us to extract information about the physical parameters of disks. With this purpose we perform a statistical analysis of principal components and a multiple linear correlation on our set of results from the models. We also present prospects for future molecular line observations of protoplanetary disks using SMA and ALMA.

Accepted by Revista Mexicana de Astronomía y Astrofísica,

http://arxiv.org/abs/astro-ph/0703291

Near- and Far-Infrared Counterparts of Millimeter Dust Cores in the Vela Molecular Ridge Cloud D

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Aims. Identify the young protostellar counterparts associated to dust millimeter cores of the Vela Molecular Ridge Cloud D through new IR observations (H_2 narrow-band at 2.12 μm and N broad band at 10.4 μm) along with an investigation performed on the existing IR catalogues.
Methods. The association of *mm* continuum emission with infrared sources from catalogues (IRAS, MSX, 2MASS), *JHK* data from the literature and new observations, has been established according to spatial coincidence, infrared colours and spectral energy distributions.
Results. Only 7 out of 29 resolved *mm* cores (and 16 out of the 26 unresolved ones) do not exhibit signposts of star formation activity. The other ones are clearly associated with: far-IR sources, H_2 jets pointing back to embedded objects not (yet) detected or near-IR objects showing a high intrinsic colour excess. The distribution of the spectral indices pertaining to the associated sources is peaked at values typical of Class I objects, while three objects are signalled as candidates Class 0 sources. Objects with far-IR colours similar to those of T-Tauri and Herbig Ae/Be stars seem to be very few. An additional population of young objects exists associated not with the *mm*-cores, but with both the diffuse warm dust emission and the gas filaments. We remark the high detection rate (30%) of H_2 jets driven by sources located inside the *mm*-cores. They appear not driven by the most luminous objects in the field, but rather by less luminous objects in young clusters, testifying the co-existence of both low- and intermediate-mass star formation.
Conclusions. The presented results reliably describe the young population of VMR-D. However, the statistical evaluation of activity vs inactivity of the investigated cores, even in good agreement with results found for other star forming regions, seems to reflect the limiting sensitivity of the available facilities rather than any property intrinsic to the *mm*-condensations.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/0704.1228

Isotopic ethyl cyanide $^{13}CH_3CH_2CN$, $CH_3{}^{13}CH_2CN$, and $CH_3CH_2{}^{13}CN$: laboratory rotational spectrum and detection in Orion

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Context. Astronomical spectra of hot molecular clouds in the wavelength range from centimeter to submillimeter show a huge number of rotational lines due to the emission of complex organic molecules, and a large fraction of these lines are unidentified. The assignment of these unidentified lines to new molecules, to known molecules in excited states, or to their isotopologues requires a good knowledge of the spectroscopic parameters of these molecules.

Aims. We present the experimental study of the spectroscopic properties of ^{13}C-substituted ethyl cyanide $^{13}CH_3CH_2CN$, $CH_3^{13}CH_2CN$, and $CH_3CH_2^{13}CN$.

Methods. The rotational spectra of the three species in the ground state have been measured in the frequency ranges from 5 to 26 GHz using waveguide Fourier transform spectrometers and from 160 to 360 GHz using a source-modulated spectrometer employing backward-wave oscillators (BWOs).

Results. A new accurate set of spectroscopic constants has been determined for each isotopic species. This permits prediction of the position of rotational lines that are best suited for detection with an accuracy of a few hundreds of kHz. The three isotopologues have been detected in an Orion IRc2 IRAM survey via several hundred of lines, illustrating that many "unidentified" bands are definitely due to isotopologues of known molecules.

Published by Astronomy & Astrophysics (Vol. 466, p. 255)

Warm HCN, C_2H_2, and CO in the disk of GV Tau

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We present the first high-resolution, ground-based observations of HCN and C_2H_2 toward the T Tauri binary star system GV Tau. We detected strong absorption due to HCN ν_3 and weak C_2H_2 (ν_3 and $\nu_2 + (\nu_4 + \nu_5)^0_+$) absorption toward the primary (GV Tau S) but not the infrared companion. We also report CO column densities and rotational temperatures, and present abundances relative to CO of HCN/CO $\sim$ 0.6% and C_2H_2/CO $\sim$ 1.2% and an upper limit for CH_4/CO $<$ 0.37% toward GV Tau S. Neither HCN nor C_2H_2 were detected toward the infrared companion and results suggest that abundances may differ between the two sources.

Accepted by The Astrophysical Journal

X-ray emission from classical T Tauri stars: Accretion shocks and coronae?

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Classical T Tauri stars (CTTS) are surrounded by actively accreting disks. According to current models material falls along the magnetic field lines from the disk with more or less free-fall velocity onto the star, where the plasma heats up and generates X-rays.We want to quantitatively explain the observed high energy emission and measure the infall parameters from the data. Absolute flux measurements allow to calculate the filling factor and the mass accretion rate. We use a numerical model of the hot accretion spot and solve the conservation equations. A comparison to data from XMM-Newton and *Chandra* shows that our model reproduces the main features very well. It yields for TW Hya a filling factor of 0.3 % and a mass accretion rate $2 \times 10^{-10}\ M_\odot\ \mathrm{yr}^{-1}$.

Accepted by A&A

http://de.arxiv.org/abs/astro-ph/0702579

The Spitzer c2d Survey of Large, Nearby, Interstellar Clouds. IX. The Serpens YSO Population as Observed with IRAC and MIPS

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We discuss the results from the combined IRAC and MIPS c2d Spitzer Legacy observations of the Serpens star-forming region. In particular we present a set of criteria for isolating bona fide young stellar objects, YSO's, from the extensive background contamination by extra-galactic objects. We then discuss the properties of the resulting high confidence set of YSO's. We find 235 such objects in the 0.85 deg^2 field that was covered with both IRAC and MIPS. An additional set of 51 lower confidence YSO's outside this area is identified from the MIPS data combined with 2MASS photometry. To understand the properties of the circumstellar material that produces the observed infrared emission, we describe two sets of results, the use of color-color diagrams to compare our observed source properties with those of theoretical models for star/disk/envelope systems and our own modeling of the subset of our objects that appear to be well represented by a stellar photosphere plus circumstellar disk. These objects exhibit a very wide range of disk properties, from many that can be fit with actively accreting disks to some with both passive disks and even possibly debris disks. We find that the luminosity function of YSO's in Serpens extends down to at least a few $\times10^{-3}$ L$_\odot$ or lower for an assumed distance of 260 pc. The lower limit may be set by our inability to distinguish YSO's from extra-galactic sources more than by the lack of YSO's at very low luminosities. We find no evidence for variability in the shorter IRAC bands between the two epochs of our data set, $\Delta t \sim 6$ hours. A spatial clustering analysis shows that the nominally less-evolved YSO's are more highly clustered than the later stages and that the background extra-galactic population can be fit by the same two-point correlation function as seen in other extra-galactic studies. We also present a table of matches between several previous infrared and X-ray studies of the Serpens YSO population and our Spitzer data set. The clusters in Serpens have a very high surface density of YSOs, primarily with SEDs suggesting extreme youth. The total number of YSOs, mostly Class II, is greater in the region outside the clusters.

Accepted by Astrophysical Journal

http://peggysue.as.utexas.edu/SIRTF/

The Spitzer c2d Survey of Large, Nearby, Interstellar Clouds VIII. Serpens Observed with MIPS

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We present maps of 1.5 square degrees of the Serpens dark cloud at 24, 70, and 160μm observed with the Spitzer Space Telescope MIPS Camera. We describe the observations and briefly discuss the data processing carried out by the c2d

team on these data. More than 2400 compact sources have been extracted at 24μm, nearly 100 at 70μm, and 4 at 160μm. We estimate completeness limits for our 24μm survey from Monte Carlo tests with artificial sources inserted into the Spitzer maps. We compare source counts, colors, and magnitudes in the Serpens cloud to two reference data sets, a 0.50 deg^2 set on a low-extinction region near the dark cloud, and a 5.3 deg^2 subset of the SWIRE ELAIS N1 data that was processed through our pipeline. These results show that there is an easily identifiable population of young stellar object candidates in the Serpens Cloud that is not present in either of the reference data sets. We also show a comparison of visual extinction and cool dust emission illustrating a close correlation between the two, and find that the most embedded YSO candidates are located in the areas of highest visual extinction.

Accepted by Astrophysical Journal

http://peggysue.as.utexas.edu/SIRTF/

Sub-arcsecond resolution radio continuum observations of IRAS 20126+4104

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Context. The detailed physical processes that lead to the formation of massive stars are still unknown. Observations that probe linear scales as small as 100 AU are necessary for improving our understanding in this area.

Aims. We present high angular-resolution and high-sensitivity multi-frequency radio observations of the deeply embedded massive protostar located in the IRAS 20126+4104 core region, with the aim of investigating the nature of the radio continuum emission from the deeply embedded massive protostar.

Methods. The observations were performed with the Very Large Array in several continuum bands with wavelengths between 20 and 0.7 cm in the A and/or B configurations.

Results. At 3.6 cm we resolve the emission of the IRAS 20126+4104 core into 3 components. The emission from the two northern sources is consistent with free-free emission from ionized gas with a density gradient. Most likely the ionization is caused by UV radiation from the cooling region of a shock; i.e. the ionization is caused by the jet driven by the IRAS 20126+4104 protostar. The morphology and measured flux densities of the southern source is consistent with emission from an optically thin jet, most likely also due to shock ionization. A simple radiative transfer model shows that the spectral energy distribution of IRAS 20126+4104 is consistent with an accretion disk embedded in a spherical halo. We also report the discovery of a highly variable radio source near the IRAS 20126+4104 core, which is most likely gyrosynchotron emission from a low-mass pre-main sequence star.

Published by Astronomy & Astrophysics (Vol. 465, p. 197)

An X-Ray Spectral Classification Algorithm with Application to Young Stellar Clusters

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A large volume of low signal-to-noise, multidimensional data is available from the CCD imaging spectrometers aboard the Chandra X-Ray Observatory and the X-Ray Multimirror Mission (XMM-Newton). To make progress analyzing this data, it is essential to develop methods to sort, classify, and characterize the vast library of X-ray spectra in a nonparametric fashion (complementary to current parametric model fits). We have developed a spectral classification

algorithm that handles large volumes of data and operates independently of the requirement of spectral model fits. We use proven multivariate statistical techniques including principal component analysis and an ensemble classifier consisting of agglomerative hierarchical clustering and K-means clustering applied for the first time for spectral classification. The algorithm positions the sources in a multidimensional spectral sequence and then groups the ordered sources into clusters based on their spectra. These clusters appear more distinct for sources with harder observed spectra. The apparent diversity of source spectra is reduced to a three-dimensional locus in principal component space, with spectral outliers falling outside this locus. The algorithm was applied to a sample of 444 strong sources selected from the 1616 X-ray emitting sources detected in deep Chandra imaging spectroscopy of the Orion Nebula Cluster. Classes form sequences in N_H, A_V, and accretion activity indicators, demonstrating that the algorithm efficiently sorts the X-ray sources into a physically meaningful sequence. The algorithm also isolates important classes of very deeply embedded, active young stellar objects, and yields trends between X-ray spectral parameters and stellar parameters for the lowest mass, premain-sequence stars.

Published by The Astrophysical Journal (Vol. 659, p. 585)

Dynamical Formation of the Dark Molecular Hydrogen Clouds around Diffuse HII Regions

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We examine the triggering process of molecular cloud formation around diffuse H II regions. We calculate the time evolution of the shell as well as of the H II region in a two-phase neutral medium, solving the UV and FUV radiative transfer, the thermal and chemical processes in the time-dependent hydrodynamics code. In the cold neutral medium, the ambient gas is swept up in the cold ($T \sim 30 - 40$ K) and dense ($n \sim 10^3$ cm^{-3}) shell around the HII region. In the shell, H_2 molecules are formed from the swept-up H I gas, but CO molecules are hardly formed. This is due to the different efficiencies of the self-shielding effects between H_2 and CO molecules. The reformation of H_2 molecules is more efficient with a higher-mass central star. The physical and chemical properties of gas in the shell are just intermediate between those of the neutral medium and molecular clouds observed by CO emissions. The dense shell with cold HI/H_2 gas easily becomes gravitationally unstable, and breaks up into small clouds. The cooling layer just behind the shock front also suffers from thermal instability, and will fragment into cloudlets with some translational motions. We suggest that the predicted cold "dark" HI/H_2 gas should be detected as the H I self-absorption (HISA) feature. We have sought such features in recent observational data, and found shell-like HISA features around the giant H II regions, W4 and W5. The shell-like HISA feature shows good spatial correlation with dust emission, but poor correlation with CO emission. Our quantitative analysis shows that the HISA cloud can be as cold as $T \sim$ a few $\times$ 10 K. In the warm neutral medium, on the other hand, the expanding diffuse H II region is much simpler owing to the small pressure excess. The UV photons only ionize the neutral medium and produce a warm ionized medium.

Accepted by ApJ

astro-ph/0605648

The spectral study of the HH43 Herbig-Haro object

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Results of the integral-field spectroscopy of HH 43 are presented. Spectra were obtained with the multi-pupil spectrograph in 6400-6800 Å range. Using the emission lines intensities ratios and radial velocities we got more specific picture of the processes taking place in this object, which belongs to the rare class of the 'shocked cloudlets'. In particular, the location of the shock wave, which supports this classification, is determined. The rate of mass loss from the source star is also estimated.

Accepted by Astrophysics

Millimeter imaging of HD163296: probing the disk structure and kinematics

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We present new multi-wavelength millimeter interferometric observations of the Herbig Ae star HD 163296 obtained with the IRAM/PBI, SMA and VLA arrays both in continuum and in the ^{12}CO, ^{13}CO and C^{18}O emission lines. Gas and dust properties have been obtained comparing the observations with self-consistent disk models for the dust and CO emission. The circumstellar disk is resolved both in the continuum and in CO. We find strong evidence that the circumstellar material is in Keplerian rotation around a central star of 2.6 $M_\odot$. The disk inclination with respect to the line of sight is 46$^o\pm$4^o with a position angle of 128$^o\pm$4^o. The slope of the dust opacity measured between 0.87 and 7 mm ($\beta = 1$) confirms the presence of mm/cm-size grains in the disk midplane. The dust continuum emission is asymmetric and confined inside a radius of 200 AU while the CO emission extends up to 540 AU. The comparison between dust and CO temperature indicates that CO is present only in the disk interior. Finally, we obtain an increasing depletion of CO isotopomers from ^{12}CO to ^{13}CO and C^{18}O. We argue that these results support the idea that the disk of HD 163296 is strongly evolved. In particular, we suggest that there is a strong depletion of dust relative to gas outside 200 AU; this may be due to the inward migration of large bodies that form in the outer disk or to clearing of a large gap in the dust distribution by a low mass companion.

Accepted by A&A

http://www.arxiv.org/abs/0704.0616

Signatures of Planet Formation in Gravitationally Unstable Disks

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In this Letter, we calculate simulated scattered light images of a circumstellar disk in which a planet is forming by gravitational instability. The simulated images bear no correlation to the vertically integrated surface density of the disk, but rather trace the density structure in the tenuous upper layers of the disk. Although the density at high altitudes does not bear a direct relation to activity at the midplane, the very existence of structure at high altitudes along with high time variability is an indicator of gravitational instability within the disk. The timescale for variations is much shorter than the orbital period of the planet, which facilitates observation of the phenomenon. Scattered light images may not necessarily be able to tell us where exactly a planet might be forming in a disk but can still be a useful probe of active planet formation within a circumstellar disk. Although these phenomena are unlikely to be observable by current telescopes, future large telescopes, such as the Giant Magellan Telescope, may be able to detect them.

Published by The Astrophysical Journal Letters (Vol. 659, p. L169)

Periodic accretion from a circumbinary disk in the young binary UZ Tau E

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Close pre–main-sequence binary stars are expected to clear central holes in their protoplanetary disks, but the extent to which material can flow from the circumbinary disk across the gap onto the individual circumstellar disks has been unclear. In binaries with eccentric orbits, periodic perturbation of the outer disk is predicted to induce mass flow across the gap, resulting in accretion that varies with the binary period. This accretion may manifest itself observationally as periodic changes in luminosity. Here we present a search for such periodic accretion in the pre–main-sequence spectroscopic binary UZ Tau E. We present *BVRI* photometry spanning three years; we find that the brightness of UZ Tau E is clearly periodic, with a best-fit period of 19.16 ± 0.04 days. This is consistent with the spectroscopic binary period of 19.13 days, refined here from analysis of new and existing radial velocity data. The brightness of UZ Tau E shows significant random variability, but the overall periodic pattern is a broad peak in enhanced brightness, spanning more than half the binary orbital period. The variability of the Hα line is not as clearly periodic, but given the sparseness of the data, some periodic component is not ruled out. The photometric variations are in good agreement with predictions from simulations of binaries with orbital parameters similar to those of UZ Tau E, suggesting that periodic accretion does occur from circumbinary disks, replenishing the inner circumstellar disks and possibly extending the timescale over which they might form planets.

Accepted by Astron. J.; to appear July 2007

Preprint at http://astro.swarthmore.edu/~jensen/publications.html

Accretion disc viscosity: how big is alpha?

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We consider observational and theoretical estimates of the accretion disc viscosity parameter . We find that in thin, fully ionized discs, the best observational evidence suggests a typical range ∼ 0.1-0.4, whereas the relevant numerical simulations tend to derive estimates for α which are an order of magnitude smaller. We discuss possible reasons for this apparent discrepancy.

Published by Monthly Notices of the Royal Astronomical Society (Vol. 376, p. 1740)

Resolving the B[e] star Hen 3-1191 at 10 μm with VLTI/MIDI

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We report spatially resolved, spectrally dispersed N-band observations of the B[e] star Hen 3-1191 with the MIDI instrument of the Very Large Telescope Interferometer. The object is resolved with a 40 m baseline and has an equivalent uniform disc diameter ranging from 24 mas at 8 μm to 36 mas at 13 μm. The MIDI spectrum and visibilities show a curvature which can arise from a weak silicate feature in which the object appears ≈ 15% larger than in the continuum, but this could result from a change in the object's geometry within the band.

We then model Hen 3-1191's spectral energy distribution (.4–60 μm) and N-band visibilities. Because of the unknown nature for the object, we use a wide variety of models for objects with IR excesses. We find the observations to be consistent with a disc featuring an unusually high mass accretion and a large central gap almost void of matter, an excretion disc, and a binary made of two IR sources. We are unable to find a circumstellar shell model consistent with the data.

At last, we review the different hypotheses concerning the physical nature of the star and conclude that it is neither a Be supergiant nor a symbiotic star. However, we could not discriminate between the scenario of a young stellar object featuring an unusually strong FU Orionis-like outburst of mass accretion ($4 - 250 \times 10^{-4}\,M_{\odot}$/yr) and that of a protoplanetary nebula with an equatorial mass excretion rate $> 4 \times 10^{-5}\,M_{\odot}$/yr. In both cases, taking the additional

presence of an envelope or wind into account would result in lower mass flows.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/astro-ph/0703736

Parker Instability in a Self-gravitating Magnetized Gas Disk. I. Linear Stability Analysis

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To be a formation mechanism of such large-scale structures as giant molecular clouds (GMCs) and H I superclouds, the classical Parker instability driven by external gravity has to overcome three major obstacles: The convective motions accompanying the instability would generate thin sheets rather than large condensations. The degree of density enhancement achieved by the instability turns out too low to make even diffuse interstellar clouds. The time and the length scales of the instability are longer and larger than the estimated formation time and the observed mean separation of the GMCs, respectively. This study examines whether a replacement of the driving agent from the external to the self-gravity might remove these obstacles by activating the gravitational instability in the Galactic ISM disk. Self-gravitating, magnetized, gas disk bound by a hot halo medium is subject to a Parker-type instability, the usual Jeans gravitational instability, and convection. Under the external gravity growth rate of the convection triggered by interchange mode perturbations increases without bound as the perturbation wavelength decreases; however, under the self-gravity, it reaches a finite value asymptotically. The presence of self-gravity can suppress the convective motions and enhance the density sufficiently high to form clouds. However, the mass and mean separation of the structures resulting from odd-parity undular mode perturbations under the self-gravity are consistent with the H I superclouds rather than the GMCs. To have structures of both scales, it seems necessary to consider a sum of the self and external gravities as the driving agent of the Parker instability.

Published by The Astrophysical Journal Supplement Series (Vol. 169, p. 269)

Methanol as a diagnostic tool of interstellar clouds: II. Modelling high-mass protostellar objects

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Context. Fundamental properties of interstellar clouds must be known to investigate the initial conditions of star formation within them and the interaction of newly formed stars with their environment. Methanol has proven to be useful to probe densities and temperatures of various environments within interstellar clouds.

Aims. We aim to explore the potential of methanol as a tracer molecule for regions in which high-mass stars are forming or have recently formed, in particular so-called high-mass protostellar objects (HMPOs) and infrared dark clouds (IRDCs).

Methods. We present and analyse multi-frequency centimetre and (sub)millimetre single-dish observations of methanol toward a sample of 13 sources that are in the poorly understood earliest phases of evolution of high-mass stars (HMPOs and IRDCs). For each source in our sample, we derive physical parameters such as the kinetic temperature, the spatial density. and the methanol column density. We apply our large velocity gradient modelling and fitting technique that involves fitting a synthetic spectrum to all the measured lines simultaneously.

Results. In several sources, we find that more than one physical component is necessary to fit the spectra; moreover, broad non-Gaussian linewidths suggest outflows in many sources from both the IRDC and the HMPO subsamples. Kinetic temperatures are found to be between 10 and 60 K and spatial densities in the range 10^5-10^6 cm^{-3}. Hotter, denser cores are found in a few HMPOs, indicating that these sources already harbour hot cores heated by protostars.

Published by Astronomy & Astrophysics (Vol. 466, p. 215)

The Lupus Association of Pre-Main Sequence Stars: Clues to Star Formation Scattered in Space and Time

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Kinematical analysis of spectroscopically identified pre-main-sequence stars associated with the Lupus dark cloud reveals a streamlike motion of low internal velocity dispersion (≥ 1.3 km s^{-1}). A statistically significant mismatch between the convergent point radial velocity and the spectroscopic radial velocity from the literature indicates a moderate degree of expansion. The rate of expansion is too low to account for the present extent of the association if one assumes that the spatially dispersed population was formed in the dense molecular cores observed today. Therefore, it is unlikely that the outlying weak-lined T Tauri members were born in the same star-forming cores as the more compactly located classical T Tauri stars, despite the kinematic integrity of the association. Distances inferred from the classical moving-cluster method show a large depth of the association (~ 80 pc) along the line of sight. A color-magnitude diagram of the association in the near-IR colors corrected for the distribution of distances shows a clear gap separating the older (5-27 Myr) and the younger (~ 1 Myr) generations of stars. Half of the identified 1 Myr old stars lie in the tight group of mostly classical T Tauri stars associated with the Lupus 3 dark filament. This nest of very young stars appears to be 25 pc farther from the Sun than the center of the greater Lupus association.

Published by The Astrophysical Journal Letters (Vol. 658, p. 480)

Medium resolution 2.3μm spectroscopy of the massive Galactic open cluster Westerlund 1

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The Galactic open cluster Westerlund 1 was found only a few years ago to be much more massive than previously thought, with evidence suggesting its mass to be in excess of $\sim 10^5$ M$_\odot$, in the range spanned by young extragalactic star clusters. Unlike those clusters, its proximity makes spatially resolved studies of its stellar population feasible. It is therefore an ideal template for a young, massive star cluster, permitting direct comparison of its properties with measurements of velocity dispersion and dynamical mass for spatially unresolved extragalactic clusters.

To this end, we used the long slit near-infrared spectrograph VLT/ISAAC to observe the CO bandhead region near 2.29μm, scanning the slit across the cluster centre during the integration. Spatially collapsing the spectra along the slit results in a single co-added spectrum of the cluster, comparable to what one would obtain in the extragalactic cluster context. This spectrum was analysed in the same way as the spectra of almost point-like extragalactic clusters, using red superiant cluster members as velocity templates. We detected four red supergiants that are included in the integrated spectrum, and our measured velocity dispersion is 5.8 km s^{-1}. Together with the cluster size of 0.86 pc, derived from archival near-infrared SOFI-NTT images, this yields a dynamical mass of 6.3×10^4 M$_\odot$. While this value is not to be considered the final word, there is at least so far no sign of rapid expansion or collapse.

Published by Astronomy & Astrophysics (Vol. 466, p. 151)

Binary Capture Rates for Massive Protostars

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The high multiplicity of massive stars in dense, young clusters is established early in their evolution. The mechanism behind this remains unresolved. Recent results suggest that massive protostars may capture companions through disk interactions with much higher efficiency than their solar mass counterparts. However, this conclusion is based on analytic determinations of capture rates and estimates of the robustness of the resulting binaries. We present the results of coupled n-body and SPH simulations of star-disk encounters to further test the idea that disk-captured

binaries contribute to the observed multiplicity of massive stars.

Accepted by ApJ Letters

http://arxiv.org/abs/0704.1162

Demographics of Transition Objects

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The unusual properties of transition objects (young stars with an optically thin inner disc surrounded by an optically thick outer disc) suggest that significant disc evolution has occured in these systems. We explore the nature of these systems by examining their demographics, specifically their stellar accretion rates (Mdot) and disc masses (Mdisc) compared to those of accreting T Tauri stars of comparable age. We find that transition objects in Taurus occupy a restricted region of the Mdot vs. Mdisc plane. Compared to non-transition single stars in Taurus, they have stellar accretion rates that are typically ~ 10 times lower at the same disc mass and median disc masses ~ 4 times larger. These properties are anticipated by several proposed planet formation theories and suggest that the formation of Jovian mass planets may play a significant role in explaining the origin of at least some transition objects. Considering transition objects as a distinct demographic group among accreting T Tauri stars leads to a tighter relationship between disc masses and stellar accretion rates, with a slope between the two quantities that is close to the value of unity expected in simple theories of disc accretion.

Accepted by MNRAS

Near-Infrared Extinction in the Coalsack Globule 2

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We have conducted J, H, and K_s imaging observations of the Coalsack Globule 2 with the SIRIUS infrared camera on the IRSF 1.4 m telescope at SAAO and determined the color excess ratio, E^{J-H}/E^{H-K_s}. The ratio is determined in the same photometric system as our previous study of the ρ Oph and Cha clouds without any color transformation; this enables us to directly compare the near-infrared extinction laws among these regions. The current ratio, $E^{J-H}/E^{H-K_s} = 1.91 \pm 0.01$ for the extinction range $0.5 < E^{J-H} < 1.8$, is significantly larger than the ratios for the ρ Oph and Cha clouds (E^{J-H}/E^{H-K_s} = 1.60-1.69). This ratio corresponds to a large negative index $\alpha = 2.34 \pm 0.01$ when the wavelength dependence of extinction is approximated by a power law $A_\lambda \propto \lambda^{-\alpha}$, which in this cloud might indicate little growth of dust grains, larger abundance of dielectric nonabsorbing components, such as silicates, or both. We also confirm that the color excess ratio for the Coalsack Globule 2 has a trend of increasing with decreasing optical depth, which is the same trend as for the ρ Oph and Cha clouds.

Published by The Astrophysical Journal (Vol. 658, p. 1114)

New HH Objects in the Star Formation Regions: Parsec-scale Outflows in the Vicinity of GM 2-30

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The star formation region in the l=33°.30, b=0°.25 molecular cloud with 1.7 kps distance is studied. The GM 2-30 nebula is embedded in this cloud. Aside of already known HH 172 object several new HH objects are discovered. They belong to at least two flows. The morphology of these objects is studied. The emission line ratios and kinematical data, obtained by multipupil spectroscopy, reveal the bipolar structure of the outflow, connected with the GM 2-30 nebula, HH 172 and HH 721. Some parameters of these two objects show mirror symmetry. The source of this outflow is not visible in optics. The faint star, connected with HH 723, can be the source of the second outflow. The linear dimensions (more than 1 ps) show that these flows can be of giant scale.

Accepted by Astronomy Reports

Herbig Ae/Be Stars in the Magellanic Bridge

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We have found Herbig Ae/Be star candidates in the western region of the Magellanic Bridge. Using the near-infrared camera SIRIUS and the 1.4 m telescope IRSF, we surveyed $\sim 3.0° \times 1.3°$ ($24° \lesssim \alpha \lesssim 36°$, $-75.0° \lesssim \delta \lesssim -73.7°$) in the J, H, and K_s bands. On the basis of colors and magnitudes, about 200 Herbig Ae/Be star candidates are selected. Considering the contaminations by miscellaneous sources, such as foreground stars and early-type dwarfs in the Magellanic Bridge, we estimate that about 80 ($\approx 40\%$) of the candidates are likely to be Herbig Ae/Be stars. We also found one concentration of the candidates at the young star cluster NGC 796, strongly suggesting the existence of pre-main-sequence (PMS) stars in the Magellanic Bridge. This is the first detection of PMS star candidates in the Magellanic Bridge, and if they are genuine PMS stars, this could be direct evidence of recent star formation. However, the estimate of the number of Herbig Ae/Be stars depends on the fraction of classical Be stars, and thus a more precise determination of the Be star fraction or observations to differentiate between the Herbig Ae/Be stars and classical Be stars are required.

Published by The Astrophysical Journal (Vol. 658, p. 358)

On the common origin of the AB Dor moving group and the Pleiades cluster

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AB Dor is the nearest identified moving group. As with other such groups, the age is important for understanding of several key questions. It is important, for example, in establishing the origin of the group and also in comparative studies of the properties of planetary systems, eventually surrounding some of the AB Dor group members, with those existing in other groups. For AB Dor two rather different estimates for its age have been proposed: a first one, of the order of 50 Myr, by Zuckerman and coworkers from a comparison with Tucana / Horologium moving group and a second one of about 100−125 Myr by Luhman and coworkers from color-magnitude diagrams (CMD). Using this last value and the closeness in velocity space of AB Dor and the Pleiades galactic cluster, Luhman and coworkers suggested coevality for these systems. Because strictly speaking such a closeness does not still guarantee coevality, here we address this problem by computing and comparing the full 3D orbits of AB Dor, Pleiades, α Persei and IC 2602. The latter two open clusters have estimated ages of about $85 - 90$ Myr and 50 Myr. The resulting age 119 ± 20 Myr is consistent with AB Dor and Pleiades being coeval. Our solution and the scenario of open cluster formation proposed by Kroupa and collaborators suggest that the AB Dor moving group may be identified with the expanding subpopulation (Group I) present in this scenario. We also discuss other related aspects as iron and lithium abundances, eventual stellar mass segregation during the formation of the systems and possible fraction of debris discs in AB Dor group.

Accepted by MNRAS

Detection of [Ne II] Emission from Young Circumstellar Disks

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We report the detection of [Ne II] emission at 12.81 micron in four out of the six optically thick dust disks observed as part of the FEPS Spitzer Legacy program. In addition, we detect a H I(7-6) emission line at 12.37 micron from the source RXJ1852.3-3700. Detections of [Ne II] lines are favored by low mid-infrared excess emission. Both stellar X-rays and extreme UV (EUV) photons can sufficiently ionize the disk surface to reproduce the observed line fluxes, suggesting that emission from Ne+ originates in the hot disk atmosphere. On the other hand, the H I(7-6) line is not associated with the gas in the disk surface and magnetospheric accretion flows can account for at most $\sim$30% of the observed flux. We conclude that accretion shock regions and/or the stellar corona could contribute to most of the H I(7-6)emission. Finally, we discuss the observations necessary to identify whether stellar X-rays or EUV photons are the dominant ionization mechanism for Ne atoms. Because the observed [Ne II] emission probes very small amounts of gas in the disk surface ($\sim 10^{-6}$ M_J) we suggest using this gas line to determine the presence or absence of gas in more evolved circumstellar disks.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/astro-ph/0703616

A Magnetically Supported Photodissociation Region in M17

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The southwestern (SW) part of the Galactic H II region M17 contains an obscured ionization front that is most easily seen at infrared and radio wavelengths. It is nearly edge-on, thus offering an excellent opportunity to study the way in which the gas changes from fully ionized to molecular as radiation from the ionizing stars penetrates into the gas. M17 is also one of the very few H II regions for which the magnetic field strength can be measured in the photodissociation region (PDR) that forms the interface between the ionized and molecular gas. Here we model an observed line of sight through the gas cloud, including the H^+, H^0 (PDR), and molecular layers, in a fully self-consistent single calculation. An interesting aspect of the M17 SW bar is that the PDR is very extended. We show that the strong magnetic field

that is observed to be present inevitably leads to a very deep PDR, because the structure of the neutral and molecular gas is dominated by magnetic pressure, rather than by gas pressure, as previously had been supposed. We also show that a wide variety of observed facts can be explained if a hydrostatic geometry prevails, in which the gas pressure from an inner X-ray hot bubble and the outward momentum of the stellar radiation field compress the gas and its associated magnetic field in the PDR, as has already been shown to occur in the Orion Nebula. The magnetic field compression may also amplify the local cosmic-ray density. The pressure in the observed magnetic field balances the outward forces, suggesting that the observed geometry is a natural consequence of the formation of a star cluster within a molecular cloud.

Published by The Astrophysical Journal (Vol. 658, p. 1119)

Baroclinic Vorticity Production in Protoplanetary Disks. I. Vortex Formation

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The formation of vortices in protoplanetary disks is explored via pseudospectral numerical simulations of an anelastic-gas model. This model is a coupled set of equations for vorticity and temperature in two dimensions that includes baroclinic vorticity production and radiative cooling. Vortex formation is unambiguously shown to be caused by baroclinicity, because (1) these simulations have zero initial perturbation vorticity and a nonzero initial temperature distribution, and (2) turning off the baroclinic term halts vortex formation, as shown by an immediate drop in kinetic energy and vorticity. Vortex strength increases with larger background temperature gradients, warmer background temperatures, larger initial temperature perturbations, higher Reynolds number, and higher resolution. In the simulations presented here, vortices form when the background temperatures are ~ 200 K and vary radially as $r^{-0.25}$, the initial vorticity perturbations are zero, the initial temperature perturbations are 5% of the background, and the Reynolds number is 10^9. A sensitivity study consisting of 74 simulations showed that as resolution and Reynolds number increase, vortices can form with smaller initial temperature perturbations, lower background temperatures, and smaller background temperature gradients. For the parameter ranges of these simulations, the disk is shown to be convectively stable by the Solberg-Høiland criteria.

Published by The Astrophysical Journal (Vol. 658, p. 1236)

Baroclinic Vorticity Production in Protoplanetary Disks. II. Vortex Growth and Longevity

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The factors affecting vortex growth in convectively stable protoplanetary disks are explored using numerical simulations of a two-dimensional anelastic-gas model that includes baroclinic vorticity production and radiative cooling. The baroclinic feedback, in which anomalous temperature gradients produce vorticity through the baroclinic term and vortices then reinforce these temperature gradients, is found to be an important process in the rate of growth of vortices in the disk. Factors that strengthen the baroclinic feedback include fast radiative cooling, high thermal diffusion, and large radial temperature gradients in the background temperature. When the baroclinic feedback is sufficiently strong, anticyclonic vortices form from initial random perturbations and maintain their strength for the

duration of the simulation, for over 600 orbital periods. Based on both simulations and a simple vortex model, we find that the local angular momentum transport due to a single vortex may be inward or outward, depending on its orientation. The global angular momentum transport is highly variable in time and is sometimes negative and sometimes positive. This result is for an anelastic-gas model and does not include shocks that could affect angular momentum transport in a compressible-gas disk.

Published by The Astrophysical Journal (Vol. 658, p. 1252)

High resolution simulations of a variable HH jet

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Context. In many papers, the flows in Herbig-Haro (HH) jets have been modeled as collimated outflows with a time-dependent ejection. In particular, a supersonic variability of the ejection velocity leads to the production of "internal working surfaces" which (for appropriate forms of the time-variability) can produce emitting knots that resemble the chains of knots observed along HH jets.

Aims. In this paper, we present axisymmetric simulations of an "internal working surface" in a radiative jet (produced by an ejection velocity variability). We concentrate on a given parameter set (i.e., on a jet with a constante ejection density, and a sinusoidal velocity variability with a 20 yr period and a 40 km s^{-1} half-amplitude), and carry out a study of the behaviour of the solution for increasing numerical resolutions.

Methods. In our simulations, we solve the gasdynamic equations together with a 17-species atomic/ionic network, and we are therefore able to compute emission coefficients for different emission lines.

Results. We compute 3 adaptive grid simulations, with 20, 163 and 1310 grid points (at the highest grid resolution) across the initial jet radius. From these simulations we see that successively more complex structures are obtained for increasing numerical resolutions. Such an effect is seen in the stratifications of the flow variables as well as in the predicted emission line intensity maps.

Conclusions. We find that while the detailed structure of an internal working surface depends on resolution, the predicted emission line luminosities (integrated over the volume of the working surface) are surprisingly stable. This is definitely good news for the future computation of predictions from radiative jet models for carrying out comparisons with observations of HH objects.

Published by Astronomy & Astrophysics (Vol. 465, p. 879)

Changes in the Radio Appearance of MWC 349A

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We present new sensitive, high angular resolution 1.3, 2, and 6 cm observations of the continuum emission from the peculiar emission-line star MWC 349A, made with the Very Large Array. This radio emission is believed to originate in an ionized flow produced by the photoevaporation of a disk that surrounds the star. We determine for the first time the proper motion of this source, which is consistent with that expected for the location of the source in the galaxy. Our analysis of the images, that include the new observations as well as archive data covering a time interval of more than 20 years, indicates that the appearance of MWC 349A has been systematically changing over time. The well-defined "hourglass" shape that characterized the 2 and 1.3 cm appearance of the source in the early 1980's has disappeared to be replaced by a more "square" shape. We discuss if these changes can be accounted for by precession of the MWC 349A disk or by intrinsic changes in the parameters of the disk, but could not reach a satisfactory explanation.

Accepted by ApJ

arXiv:astro-ph/0703735

A theoretical approach for the interpretation of pulsating PMS intermediate-mass stars

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Context. The investigation of the pulsation properties of pre-main-sequence intermediate-mass stars is a promising tool to evaluate the intrinsic properties of these stars and to constrain current evolutionary models. Many new candidates of this class have been discovered during the last decade and very accurate data are expected from space observations obtained for example with the CoRoT satellite.

Aims. In this context we aim at developing a theoretical approach for the interpretation of observed frequencies, both from the already available ground-based observations and from the future more accurate and extensive CoRoT results.

Methods. To this purpose we have started a project devoted to the computations of fine and extensive grids of asteroseismic models of intermediate mass pre-main-sequence stars. The obtained frequencies are used to derive an analytical relation between the large frequency separation and the stellar luminosity and effective temperature and to develop a tool to compare theory and observations in the echelle diagram.

Results. The predictive capabilities of the proposed method are verified through the application to two test stars. As a second step, we apply the procedure to two true observations from multisite campaigns and we are able to constrain their stellar parameters, in particular the mass, in spite of the small number of frequencies.

Conclusions. We expect that with a significantly higher number of frequencies both the stellar mass and age could be constrained and, at the same time, the physics of the models could be tested.

Published by The Astronomy & Astrophysics (Vol. 466, p. 261)

Dense Molecular Clumps Associated with Young Clusters in Massive Star-forming Regions

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We present the results of $C^{18}O$ observations by the 45 m Nobeyama radio telescope toward dense clumps with young clusters in nine massive star-forming regions. We identified 39 clumps whose mass, radius, and line width range from 15 to 1500 $M_\odot$, from 0.14 to 0.76 pc, and from 0.6 to 3.2 km s^{-1}, respectively. The clumps associated with massive (proto)stars have a large line width ($\sim$ 2.5 km s^{-1}) and a large mass ($\sim$ 500 $M_\odot$). Most of the clumps are sufficiently gravitationally bound because they have a virial mass similar to the gas mass, and the average H_2 density of the clumps increases with increasing internal kinetic motion. Next, we found two relations, one between the number density of associated 2MASS sources and the average H_2 density of the clump and the other between the number density of sources and the star formation efficiency of the clump. From these results, we suggest that a structure, whose size scale is $\sim$ 0.3 pc, with a high average H_2 density is required in order for cluster formation to occur. In addition, we found that the internal kinetic motion of a clump has to be large in order to form massive stars, because there

is a good correlation between the maximum mass of associated stars and the line width of the clump. Such clumps with large internal motion must generally have a high average H_2 density in order to be gravitationally bound. Thus, massive stars are formed in a dense cluster.

Published by The Astrophysical Journal (Vol. 659, p. 459)

PPAK integral field spectroscopy survey of the Orion nebula

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Aims. We present a low-resolution spectroscopic survey of the Orion nebula. The data are released for public use. We show the possible applications of this dataset analyzing some of the main properties of the nebula.

Methods. We perform an integral field spectroscopy mosaic of an area of $\sim 5' \times 6'$ centered on the Trapezium region of the nebula, including the ionization front to the south-east. Analysis of the line fluxes and line ratios of both the individual and integrated spectra allowed us to determine the main characteristics of the ionization throughtout the nebula.

Results. The final dataset comprises 8182 individual spectra, sampled in a circular area of $\sim 2.7''$ diameter. The data can be downloaded as a single row-stacked spectra fit file plus a position table or as an interpolated datacube with a final sampling of $1.5''$/pixel. The integrated spectrum across the field-of-view was used to obtain the main integrated properties of the nebula, including the electron density and temperature, the dust extinction, the Hα integrated flux (after correcting for dust reddening), and the main diagnostic line ratios. The individual spectra were used to obtain line intensity maps of the different detected lines. These maps were used to study the distribution of the ionized hydrogen, the dust extinction, the electron density and temperature, and the helium and oxygen abundance. All of them show a considerable degree of structure as already shown in previous studies. In particular, there is a tight relation between the helium and oxygen abundances and the ionization structure that cannot be explained by case B recombination theory. Simple arguments like partial ionization and dust mixed with the emitting gas may explain these relations. However a more detailed modeling is required, for which we provide the dataset.

Published by Astronomy & Astrophysics (Vol. 465, p. 207)

Detection of CS emission towards Cygnus OB2 No. 12

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Aims. The CS (J = 2-1) line was searched at locations with brightest ^{13}CO (J=1-0) emissions in the region in front of the star Cyg OB2 No. 12.

Methods. The observations were made with the 20-m millimeter wave telescope at Onsala using a 1024-channel autocorrelator with a resolution of 50 kHz (0.14 km s^{-1}).

Results. The line was detected only in one position (core B) with main beam brightness temperature $T_{\rm MB} = 0.15(2)$ K at $v_{\rm LSR} = 11.4(1)$ km s^{-1}.

Conclusions. The line excitation analysis suggests that core B could be a Bok globule in consideration of its morphology, chemistry and physical conditions.

Published by Astronomy & Astrophysics (Vol. 466, p. 243)

The Effect of Semicollisional Accretion on Planetary Spins

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Planetesimal accretion during planet formation is usually treated as collisionless. Such accretion from a uniform and dynamically cold disk predicts protoplanets with slow retrograde rotation. However, if the building blocks of protoplanets, planetesimals, are small, of the order of a meter in size, then they are likely to collide within the protoplanet's sphere of gravitational influence, creating a prograde accretion disk around the protoplanet. The accretion of such a disk results in the formation of protoplanets spinning in the prograde sense with the maximal spin rate allowed before centrifugal forces break them apart. As a result of semicollisional accretion, the final spin of a planet after giant impacts is not completely random, but is biased toward prograde rotation. The eventual accretion of the remaining planetesimals in the post-giant-impact phase might again be in the semicollisional regime and delivers a significant amount of additional prograde angular momentum to the terrestrial planets. We suggest that in our solar system, semicollisional accretion gave rise to the preference for prograde rotation observed in the terrestrial planets and perhaps the largest asteroids.

Published by The Astrophysical Journal (Vol. 658, p. 593)

Probing Protoplanetary Disks with Silicate Emission: Where Is the Silicate Emission Zone?

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Recent results indicate that the grain size and crystallinity inferred from observations of silicate features may be correlated with the spectral type of the central star and/or disk geometry. In this paper, we show that grain size, as probed by the 10μm silicate feature peak-to-continuum and 11.3 to 9.8μm flux ratios, is inversely proportional to log $L_\star$. These trends can be understood using a simple two-layer disk model for passive irradiated flaring disks, CGPLUS. We find that the radius, R_{10}, of the 10μm silicate emission zone in the disk goes as $(L_\star/L_\odot)^{0.56}$, with slight variations depending on disk geometry (flaring angle and inner disk radius). The observed correlations, combined with simulated emission spectra of olivine and pyroxene mixtures, imply a dependence of grain size on luminosity. Combined with the fact that R_{10} is smaller for less luminous stars, this implies that the apparent grain size of the emitting dust is larger for low-luminosity sources. In contrast, our models suggest that the crystallinity is only marginally affected, because for increasing luminosity, the zone for thermal annealing (assumed to be at $T > 800$ K) is enlarged by roughly the same factor as the silicate emission zone. The observed crystallinity is affected by disk geometry, however, with increased crystallinity in flat disks. The apparent crystallinity may also increase with grain growth due to a corresponding increase in contrast between crystalline and amorphous silicate emission bands.

Published by The Astrophysical Journal (Vol. 659, p. 680)

Hard X-Rays and Fluorescent Iron Emission from the Embedded Infrared Cluster in NGC 2071

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We present first results of XMM-Newton X-ray observations of the infrared cluster lying near the NGC 2071 reflection nebula in the Orion B region. This cluster is of interest because it is one of the closest regions known to harbor embedded high-mass stars. We report the discovery of hard X-ray emission from the dense central NGC 2071-IR subgroup, which contains at least three high-mass young stellar objects (NGC 2071 IRS 1, IRS 2, and IRS 3). A prominent X-ray source is detected within 1″ of the infrared source IRS 1, which is thought to drive a powerful bipolar molecular outflow. The X-ray spectrum of this source is quite unusual compared to the optically thin plasma spectra normally observed in young stellar objects (YSOs). The spectrum is characterized by a hard broadband continuum plus an exceptionally broad emission line at *approx* 6.4 keV from neutral or near-neutral iron. The fluorescent Fe line likely originates in cold material near the embedded star (i.e., a disk or envelope) that is irradiated by the hard, heavily absorbed X-ray source.

Published by The Astrophysical Journal (Vol. 658, p. 1144)

Hydrodynamic Simulations of Rotating Molecular Jets

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Molecular outflows and the jets which may drive them can be expected to display signatures associated with rotation if they are the channels through which angular momentum is extracted from material accreting onto protostars. Here, we determine some basic signatures of rapidly rotating flows through three dimensional numerical simulations of hydrodynamic jets with molecular cooling and chemistry. We find that these rotating jets generate a broad advancing interface which is unstable and develops into a large swarm of small bow features. In comparison to precessing jets, there is no stagnation point along the axis. The greater the rotation rate, the greater the instability. On the other hand, velocity signatures are only significant close to the jet inlet since jet expansion rapidly reduces the rotation speed. We present predictions for atomic, H_2 and CO submillimetre images and spectroscopy including velocity channel maps and position-velocity diagrams. We also include simulated images corresponding to Spitzer IRAC band images and CO emission, relevant for APEX and eventual ALMA observations. We conclude that protostellar jets often show signs of slow precession but only a few sources display properties which could indicate jet rotation.

Accepted by Monthly Notices of the Royal Astronomical Society

Preprints: http://astro.kent.ac.uk/mds/Papers/molrot.pdf

The Evolution of Massive Dense Cores

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A comparison of the line widths of $C^{17}O$ and CS toward a sample of high-mass protostar objects is used to separate the sample into two groups. The larger line width objects ($\Delta v > 3$ km s^{-1}; MC1 sources) are shown to have the lowest $C^{17}O$ abundances. They also show evidence of heating by the central young star and have steep density profiles and high mass-to-luminosity (M/L) ratios. The remaining sources show less evidence of heating and have shallower density profiles and smaller M/L ratios. These objects are subdivided into sources with low $C^{17}O$ abundances (MC2 sources) and sources with approximately normal $C^{17}O$ abundances (MC3 sources). The connection between properties related to the core ($C^{17}O$ abundance, density profile) and stellar heating suggests an intimate connection between the cores and the objects forming within them. We propose that this reflects a coupled evolution of the core and the central sources. It is proposed that the identified groups represent an evolutionary sequence in the properties of these massive cores.

Published by The Astrophysical Journal Letters (Vol. 659, p. L165)

A computer program for fast non-LTE analysis of interstellar line spectra

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The large quantity and high quality of modern radio and infrared line observations require efficient modeling techniques to infer physical and chemical parameters such as temperature, density, and molecular abundances. We present a computer program to calculate the intensities of atomic and molecular lines produced in a uniform medium, based on statistical equilibrium calculations involving collisional and radiative processes and including radiation from background sources. Optical depth effects are treated with an escape probability method. The program is available on the World Wide Web at `http://www.sron.rug.nl/~vdtak/radex/index.shtml` . The program makes use of molecular data files maintained in the Leiden Atomic and Molecular Database (LAMDA), which will continue to be improved and expanded. The performance of the program is compared with more approximate and with more sophisticated methods. An Appendix provides diagnostic plots to estimate physical parameters from line intensity ratios of commonly observed molecules. This program should form an important tool in analyzing observations from current and future radio and infrared telescopes.

Accepted by A&A

arxiv: 0704.0155

Relation between the Luminosity of Young Stellar Objects and Their Circumstellar Environment

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We present a new model-independent method of comparison of NIR visibility data of YSOs. The method is based on scaling the measured baseline with the YSO's distance and luminosity, which removes the dependence of visibility on these two variables. We use this method to compare all available NIR visibility data and demonstrate that it distinguishes YSOs of luminosity $L_\star \lesssim 10^3$ $L_\odot$ (low L) from YSOs of $L_\star \gtrsim 10^3$ $L_\odot$ (high L). This confirms earlier suggestions, based on fits of image models to the visibility data, for the difference between the NIR sizes of these two luminosity groups. When plotted against the "scaled" baseline, the visibility creates the following data clusters: low-L Herbig Ae/Be stars, T Tauri stars, and high-L Herbig Be stars. We model the shape and size of clusters with different image models and find that low-L Herbig stars are best explained by the uniform brightness ring and the halo model, T Tauri stars with the halo model, and high-L Herbig stars with the accretion disk model. However, the plausibility of each model is not well established. Therefore, we try to build a descriptive model of the circumstellar environment consistent with various observed properties of YSOs. We argue that low-L YSOs have optically thick disks with the optically thin inner dust sublimation cavity and an optically thin dusty outflow above the inner disk regions. High-L YSOs have optically thick accretion disks with high accretion rates enabling gas to dominate the NIR emission over dust. Although observations would favor such a description of YSOs, the required dust distribution is not supported by our current understanding of dust dynamics.

Published by The Astrophysical Journal (Vol. 658, p. 462)

A search for strong, ordered magnetic fields in Herbig Ae/Be stars

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The origin of magnetic fields in intermediate- and high-mass stars is fundamentally a mystery. Clues towards solving this basic astrophysical problem can likely be found at the pre-main-sequence (PMS) evolutionary stage. With this work, we perform the largest and most sensitive search for magnetic fields in PMS Herbig Ae/Be (HAeBe) stars. We seek to determine whether strong, ordered magnetic fields, similar to those of main-sequence Ap/Bp stars, can be detected in these objects, and if so, to determine the intensities, geometrical characteristics, and statistical incidence of such fields. 68 observations of 50 HAeBe stars have been obtained in circularly polarized light using the FORS1 spectropolarimeter at the ESO VLT. An analysis of both Balmer and metallic lines reveals the possible presence of weak longitudinal magnetic fields in photospheric lines of two HAeBe stars, HD 101412 and BF Ori. Results for two additional stars, CPD-53 295 and HD 36112, are suggestive of the presence of magnetic fields, but no firm conclusions can be drawn based on the available data. The intensity of the longitudinal fields detected in HD 101412 and BF Ori suggest that they correspond to globally ordered magnetic fields with surface intensities of order 1 kG. On the other hand, no magnetic field is detected in 4 other HAeBe stars in our sample in which magnetic fields had previously been confirmed. Monte Carlo simulations of the longitudinal field measurements of the undetected stars allow us to place an upper limit of about 300 G on the general presence of aligned magnetic dipole magnetic fields, and of about 500 G on perpendicular dipole fields. Taking into account the results of our survey and other published results, we find that the observed bulk incidence of magnetic HAeBe stars in our sample is 8-12 per cent, in good agreement with that of magnetic main-sequence stars of similar masses. We also find that the rms longitudinal field intensity of magnetically detected HAeBe stars is about 200 G, similar to that of Ap stars and consistent with magnetic flux conservation during stellar evolution. These results are all in agreement with the hypothesis that the magnetic fields of main-sequence Ap/Bp stars are fossils, which already exist within the stars at the PMS stage. Finally, we explore the ability of our new magnetic data to constrain magnetospheric accretion in Herbig Ae/Be stars, showing that our magnetic data are not consistent with the general occurrence in HAeBe stars of magnetospheric accretion as described by the theories of Königl and Shu et al..

Published by Monthly Notices of the Royal Astronomical Society (Vol. 376, p. 1145)

On the infant weight loss of low- to intermediate-mass star clusters

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Star clusters are born in a highly compact configuration, typically with radii of less than about 1 pc roughly independently of mass. Since the star formation efficiency is less than 50 per cent by observation and because the residual gas is removed from the embedded cluster, the cluster must expand. In the process of doing so it only retains a fraction f_{st} of its stars. To date there are no observational constraints for f_{st}, although N-body calculations by Kroupa, Aarseth & Hurley suggest it to be about 20-30 per cent for Orion-type clusters. Here we use the data compiled by Testi et al., Testi, Palla & Natta and Testi, Palla & Natta for clusters around young Ae/Be stars and by de Wit et al. and de Wit et al. around young O stars and the study of de Zeeuw et al. of OB associations and combine these measurements with the expected number of stars in clusters with primary Ae/Be and O stars, respectively, using the empirical correlation between maximal stellar mass and star cluster mass of Weidner & Kroupa. We find that $f_{st} < 50$ per cent with a decrease to higher cluster masses/more massive primaries. The interpretation would be that cluster formation is very disruptive. It appears that clusters with a birth stellar mass in the range 10-10^3 $M_\odot$ keep at most 50 per cent of their stars.

Published by Monthly Notices of the Royal Astronomical Society (Vol. 376, p. 1879)

The Transit Light Curve Project. V. System Parameters and Stellar Rotation Period of HD 189733

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We present photometry of HD 189733 during eight transits of its close-in giant planet, and out-of-transit photometry spanning 2 yr. Using the transit photometry, we determine the stellar and planetary radii and the photometric ephemeris. Outside of transits, there are quasi-periodic flux variations with a 13.4 day period that we attribute to stellar rotation. In combination with previous results, we derive upper limits on the orbital eccentricity and on the true angle between the stellar rotation axis and planetary orbit (as opposed to the angle between the projections of those axes on the sky).

Published by The Astronomical Journal (Vol. 133, p. 1828)

Steady-state evolution of debris disks around A stars

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In this paper a simple analytical model for the steady-state evolution of debris disks due to collisions is confronted with Spitzer observations of dust around main sequence A stars. All stars are assumed to have planetesimal belts with a distribution of initial masses and radii. In the model disk mass is constant until the largest planetesimals reach collisional equilibrium whereupon the mass falls off $\propto t_{age}^{-1}$. Using parameters that are reasonable within the context of planet formation models and observations of proto-planetary disks, the detection statistics and trends seen at both 24 and 70 μm can be fitted well by the model. While there is no need to invoke stochastic evolution or delayed stirring to explain the detection statistics of dust around A stars, the model is also consistent with a moderate rate of stochastic events. Potentially anomalous systems are identified by their high ratio of observed dust luminosity to the maximum permissible in the model given their radii and ages, $f/f_{\rm max}$; these are HD3003, HD38678, HD115892, and HD172555. It is not clear if their planetesimals have unusual properties (e.g., high strength or low eccentricity), or if their dust is a transient phenomenon. There are also well-studied examples from the literature where transient phenomena are favored (e.g., Vega, HD69830). However, the overall success of our model, which assumes planetesimals in all belts have the same strength, eccentricity and maximum size, suggests there is a large degree of uniformity in the outcome of planet formation. The distribution of the radii of the planetesimal belts, once corrected for detection bias, is found to follow $N(r) \propto r^{-0.8\pm0.3}$ in the range 3-120 AU. Since the inner edge of a belt is often attributed to an unseen planet, this provides a unique constraint on the planetary systems of A stars. It is also shown that the effect of P-R drag on the inner edge of A star disks may need to be considered for those close to the Spitzer detection threshold, such as

HD2262, HD19356, HD106591, and HD115892. Predictions are made for the upcoming SCUBA-2 survey, including that at least 17 of the 100 A stars should be detectable above 2 mJy at 850 μm, illustrating how this model can be readily applied to the interpretation of future surveys.

Accepted by ApJ

http://arxiv.org/abs/astro-ph/0703608

A "diamond-ring" star: the unusual morphology of a young (multiple?) object

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Aims: Our new near-infrared J and Ks-band images taken towards IRAS 06468-0325 revealed the presence of extended emission with very unusual and enigmatic morphology: that of a diamond-ring, that is, a ring or torus with a bright source overlapping the edge of it (not inside it). We report the discovery of this source, explore its nature and propose possible interpretations of its morphological structure.

Methods: We have observed IRAS 06468-0325 obtaining optical and infrared images through $IJHKs$ and L' filters, K-band low-resolution spectroscopy, together with millimetre line observations of CO(1-0), ^{13}CO(2-1), C^{18}O(2-1), and CS(2-1).

Results: Morphologically, IRAS 06468-0325 has two components: a bright, close to point-like source (the diamond) and a sharp-edge ring-like structure (the ring). The source is not detected in the optical, at wavelengths shorter than the I-band. The diamond is seen in all the imaging bands observed. The ring-like structure in IRAS 06468-0325 is clearly seen in the I, J, H, and Ks. It is not detected in the L'-band image. Infrared colours of the diamond are compatible with excess circumstellar emission and a young stellar nature. A strongly non-gaussian and moderately bright CO(1-0) and ^{13}CO(2-1) lines are seen towards IRAS 06468-0325, at v_{LSR} of 30.5 km s^{-1} (corresponding to a kinematic distance of 3 kpc). Very weak C^{18}O(2-1) and CS(2-1) lines were detected. K-band spectra of the diamond and of the ring are similar both in the slope of the continuum and in the presence of lines supporting the idea that the ring is reflected light from the diamond.

Conclusions: With the current data, a few different scenarios are possible to explain the morphology of this object. However, the available data seem to favour that the morphology of IRAS 06468-0325 correspond to a young stellar multiple system in a transient stage where a binary co-exists with a circumbinary disc, similar to the case of GG Tau. In this case, the sharpness of the well-defined ring may be due to tidal truncation from dynamic interactions between components in a binary or multiple stellar system. IRAS 06468-0325 may be an important rare case that illustrates a short-lived stage of the process of binary or multiple star formation.

Accepted by Astronomy & Astrophysics

http://astro.oal.ul.pt/yun/yun_diamondring.pdf

A Jet-like Outflow toward the High-Mass (Proto)stellar Object IRAS 18566+0408

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We performed interferometric observations of a high-mass protostellar candidate IRAS 18566+0408 in the NH_3 (J,K)=(1,1), (2,2) and (3,3) inversion transitions, the SiO J=2-1 and HCN J=1-0 lines, and the 43 and 87 GHz continuum emission using the VLA and OVRO. The 87 GHz continuum emission reveals two continuum peaks MM-1

and MM-2 along a molecular ridge. The dominant peak MM-1 coincides with a compact emission feature at 43 GHz, and arises mostly from the dust emission. For dust emissivity index β of 1.3, the masses in the dust peaks amount to 70 $M_\odot$ for MM-1, and 27 $M_\odot$ for MM-2. Assuming internal heating, the central luminosities of MM-1 and MM-2 are 6×10^4 and 8×10^3 $L_\odot$, respectively.

The SiO emission reveals a well collimated outflow emanating from MM-1. The jet-like outflow is also detected in NH_3 at velocities similar to the SiO emission. The outflow, with a mass of 27 $M_\odot$, causes significant heating (70 K) in the gas, much higher than the temperature of $\lesssim$15 K in the extended core. Compact ($< 3''$) and narrow line (< 1.5 km s^{-1}) NH_3 (3,3) emission features are found associated with the outflow. They likely arise from weak population inversion in NH_3 similar to the maser emission.

Toward MM-1, there exists a compact NH_3 structure with linewidth that increases from 5.5 km s^{-1} FHWM measured at $3''$ resolution to 8.7 km s^{-1} measured at $1''$ resolution. This linewidth is much larger than the FWHM of < 2 km s^{-1} in the entire core, and does not appear to originate from the outflow. This large linewidth may arise from rotation/infall, or relative motions of unresolved protostellar cores.

Accepted by A&A

Preprint available at arXiv:0704.2767 or http://cfa-www.harvard.edu/~qzhang/pub.html

The interaction of young massive stars with their environment - A millimeter and sub-millimeter line study of NGC6334 FIRII

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Using the 15-m Swedish ESO Sub-millimeter Telescope (SEST), CO, HCN, and HCO^+ observations of the galactic star-forming region NGC 6334 FIR II are presented, complemented by [C I] $^3P_1$-$^3P_0$ and $^3P_2$-$^3P_1$ data from the Atacama Pathfinder Experiment (APEX 12-m telescope). Embedded in the extended molecular cloud and associated with the H II region NGC 6334-D, there is a molecular "void". [C I] correlates well with ^{13}CO and other molecular lines and shows no rim brightening relative to molecular cloud regions farther off the void. While an interpretation in terms of a highly clumped cloud morphology is possible, with photon dominated regions (PDRs) reaching deep into the cloud, the data do not provide any direct evidence for a close association of [C I] with PDRs. Kinetic temperatures are $\sim$ 40-50 K in the molecular cloud and $\gtrsim$ 200 K toward the void. CO and [C I] excitation temperatures are similar. A comparison of molecular and atomic fine structure line emission with the far infrared and radio continuum as well as the distribution of 2.2 μm H_2 emission indicates that the well-evolved H II region expands into a medium that is homogeneous on pc-scales. If the H_2 emission is predominantly shock excited, both the expanding ionization front (classified as subsonic, "D-type") and the associated shock front farther out (traced by H_2) can be identified, observationally confirming for the first time a classical scenario that is predicted by evolutionary models of HII regions. Integrated line intensity ratios of the observed molecules are determined, implying a mean $C^{18}O/C^{17}O$ abundance ratio of 4.13 ± 0.13 that reflects the $^{18}O/^{17}O$ isotope ratio. This ratio is consistent with values determined in nearby clouds. Right at the edge of the void, however, the oxygen isotope ratio might be smaller.

Published by Astronomy & Astrophysics (Vol. 465, p. 887)

Formation and Collisional Evolution of Kuiper Belt Objects

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This chapter summarizes analytic theory and numerical calculations for the formation and collisional evolution of KBOs at 20–150 AU. We describe the main predictions of a baseline self-stirring model and show how dynamical perturbations from a stellar flyby or stirring by a giant planet modify the evolution. Although robust comparisons between observations and theory require better KBO statistics and more comprehensive calculations, the data are broadly consistent with KBO formation in a massive disk followed by substantial collisional grinding and dynamical ejection. However, there are important problems reconciling the results of coagulation and dynamical calculations. Contrasting our current understanding of the evolution of KBOs and asteroids suggests that additional observational constraints, such as the identification of more dynamical families of KBOs (like the 2003 EL61 family), would provide additional information on the relative roles of collisional grinding and dynamical ejection in the Kuiper Belt. The uncertainties also motivate calculations that combine collisional and dynamical evolution, a 'unified' calculation that should give us a better picture of KBO formation and evolution.

to appear in 'Transneptunian Objects', Barucci et al. eds., University of Arizona Press

preprints: astro-ph/07040259

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals), *Abstracts of recently accepted major reviews* (not standard conference contributions), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star and planet formation and early solar system community), *New Jobs* (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and *Short Announcements* (where you can inform or request information from the community).

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What's in the brew? A study of the environment of methanol masers and UCHII regions.

Cormac R. Purcell

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Ph.D degree awarded: February 2007

In recent years the 6.67 GHz masing transition of CH_3OH has proven to be a superior tracer of massive star formation. Maser sites often occur in proximity to UCHII regions, however, up to 75 per cent of sites have no detectable radio counterpart (Walsh et al. 1998) and are instead hypothesised to trace the less evolved 'hot molecular core' phase of stellar evolution. This has been confirmed for a only handful of well known sources (e.g., Cesaroni et al. 1994). Presented here are the results of multi-species molecular line observations towards warm, dusty clumps, undertaken with the goal of investigating the relationship between hot cores, UCHII regions and CH_3OH masers.

Data from the 22-m Mopra telescope is used extensively in this thesis and substantial efforts were made to calibrate the brightness temperature scale. Measurements conducted on SiO masers and planets show that the beam pattern is divided into a Gaussian main beam plus an inner error lobe, which in 2004 contained 1/3 of the power in the main beam. Full-width half-maximum beam sizes were measured from the data and the beam efficiencies were derived for the years 2000 − 2004.

A 3-mm wavelength molecular line survey was conducted, using Mopra, towards 83 massive star-forming clumps associated with CH_3OH masers. Emission from the transitions $^{13}CO\,(1-0)$, $N_2H^+\,(1-0)$, $HCO^+\,(1-0)$, $HCN\,(1-0)$ and $HNC\,(1-0)$ was detected towards 82 sources (99 per cent), while CH_3OH emission was detected towards 78 sources (94 per cent). The warm gas tracer CH_3CN was observed specifically to search for hot core chemistry, and was detected towards 58 sources (70 per cent), confirming that CH_3OH masers are excellent tracers of hot cores.

CH_3CN is found to be brighter and more commonly detected towards masers associated with UCHII regions compared to 'isolated' masers. That CH_3CN is detected towards isolated maser sources strongly suggests that these objects are internally heated.

The molecular line data have been used to derive rotational temperatures and chemical abundances in the clumps and these properties have been compared between sub-samples associated with different indicators of evolution. In particular, CH_3OH is found to be brighter and more abundant in UCHII regions and in sources with detected CH_3CN, and may constitute a crude molecular clock in single dish observations.

Gas-kinematics were analysed via asymmetries in the HCO^+ line profiles. Approximately equal numbers of red and blue-skewed profiles, indicative of inward or outward motions, respectively, are found among all classes of object.

Bolometric luminosities were derived via greybody fits to the sub-millimetre and mid-infrared spectral energy distributions, and an empirical gas-mass to luminosity relation of $L \propto M^{0.68}$ was fit to the sample. This is a considerably shallower power law than $L \propto M^3$ for massive main-sequence stars.

In the mid-infrared, 12 sources were identified as 'infrared dark clouds' (IRDCs). Such objects have been hypothesised as precursors to the hot core phase of evolution, however, we find these sources have greater linewidths and rotational temperatures than the bulk of the sample, and one contains an embedded HII region.

The filamentary star forming region NGC 3576 was also investigated via a molecular line and 23 GHz continuum mapping survey, utilising the ATCA, Mopra and Tidbinbilla telescopes. The results of these observations provide detailed information on the morphology, masses, kinematics, and physical and chemical conditions along the cloud.

Analysis of NH_3 data has revealed that the temperature and linewidth gradients exist in the western arm of the filament. Values are highest near to the central HII region, indicating that the embedded cluster of young stars is influencing the conditions in the bulk of the gas.

Six new H_2O masers were detected in the arms of the filament, all associated with clumps of NH_3 emission. Star formation is clearly underway, however, clump masses range from $1\,M_\odot$ to $128\,M_\odot$, possibly too low to harbour very massive stars. The lack of detected 23 GHz continuum emission in the arms supports this assertion.

Postdoctoral Position on "Observations and Models of Protoplanetary Disks"

A postdoctoral position is offered in the Star and Planet Formation group of the Laboratoire d'Astrophysique de Grenoble (LAOG), in France. A description of the group, members and activities, can be found at *http://www-laog.obs.ujf-grenoble.fr/equipes/fost/*

The successful candidate will collaborate with Francois Menard and several other members of the group in the area of observation and models of proto-planetary disks, with an emphasis on grain growth and multi-wavelength simultaneous image and SED fitting of disks. The fellowship will start in september 2007 and will last for one year, renewable for a second year. A detailed description of the expected research programme can be found at: https://www2.cnrs.fr/DRH/post-docs07/?pid=1&action=view&id=705 (available in english and french)

For eligibility and application details please contact Dr. Francois Menard by mail (menard@obs.ujf-grenoble.fr) or by phone (+33 (0)4 76 51 42 07) and check the CNRS web site at: *https://www2.cnrs.fr/DRH/post-docs07/*

Prior contacts and Documents should be sent by April 30th, 2007 to:
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Postdoctoral and PhD student positions in Star Formation at various European astronomical institutions

CONSTELLATION is a European Commission-funded Marie Curie Research Training Network and will be employing 17 young researchers over the next 4 years to work on the origin of stellar masses from both observational and theoretical perspectives. We are presently soliciting applications for 8 PhD studentships (3 years each, starting October 2007) and up to 5 postdoctoral positions (2 years each).

TEAMS: The institutions involved in CONSTELLATION are the University of Exeter (coordinator); Astronomical Institute Prague; Astrophysical Institute Potsdam; CEA Saclay; Cardiff University; ENS Lyon; University of Lisbon; IAC Tenerife; INAF Palermo; INAF Arcetri; LAOG Grenoble; University of Cambridge; and University of St Andrews.

SCIENCE: The young researchers will be engaged within one or more of the three network work packages: (1) from clouds to cores to protostars; (2) the birth and influence of massive stars; (3) the physics of the low-mass end of the IMF. Work in related topics such as circumstellar disks, planet formation, and young exoplanets is also possible. All of these activities will be conducted collaboratively across the network and significant inter-team travel is expected; the young researchers will also take part in a range of schools and workshops across the network as part of their training.

FACILITIES: Research facilities available to CONSTELLATION will include the ESO VLT, Gemini, GTC, VISTA, UKIRT, CFHT, JCMT, Herschel, HST, and XMM, along with supercomputers at several of the nodes.

ELIGIBILITY: Applicants must meet EC Marie Curie RTN rules concerning academic and nationality eligibility, including a transnational mobility requirement. Note that a significant fraction of the young researchers employed may be from countries outside the European Union and associated states. Successful applicants will be paid at Marie Curie rates, a generous package which includes a mobility allowance and a significant contribution to research-related expenses.

APPLYING: Applications should be made via the network website, where full details of the network structure, its science goals, and eligibility requirements can also be found:
`http://www.constellation-rtn.eu`
`http://www.constellation-rtn.eu/Positions`

For any additional questions, please contact Prof Mark McCaughrean, the network coordinator, via email to:
`positions@constellation-rtn.eu`

Evaluation of applications will begin on May 1st 2007, but will be accepted until all positions are filled.

Structure Formation in the Universe: Galaxies, Stars, Planets Chamonix, France, 27 May - 1 June 2007

This is the **last announcement** of the conference *"Structure formation in the universe"*, to be held in Chamonix, France from 27 May through 1 June 2007. The aim of the conference is to bring together researchers working in the fields of planet, star and galaxy formation in order to share their expertise and to address common physical and numerical issues in the understanding of structure formation in astrophysics.

The **registration**, with the possibility to submit a **poster presentation**, is **now open**, and hotel reservations will be closed on 30 april.

Late Registration (380 euros) and **Financial support request**: **April 30, 2007**.

Scientific rationale, final program and list of speakers on: **http://chamonix2007.ens-lyon.fr/**

Organizer and contact (financial support) : **G. Chabrier (ENS-Lyon; chabrier@ens-lyon.fr)**

4th Jetset School "From Models to Observations and Experiments"

The mechanism by which a star-disk system launches and collimates a jet is one of the yet unsolved problems in contemporary astrophysics. Testing models for jet launching and collimation requires a high degree of interdisciplinary co-operation. Indeed, closing the circle between pure MHD, thermo-chemical evolution, high angular resolution spectro-imaging and laboratory experiments is not trivial. This the fourth school and workshop in the framework of the Marie Curie RTN JETSET, aims to bridge these gaps by providing a series of lectures linking each discipline. In parallel, some space is reserved for contributed talks addressing front-line research in the field.

The school is organised by the Porto JETSET node and will be held in the Azores Islands, Portugal, from June 25th to 29th. Please see http://www.astro.up.pt/jets-4/ for further information.

2007 Gordon Conference on Origins of Solar Systems

Registration is now open for the 2007 Gordon Research Conference on Origins of Solar Systems, to be held at Mt. Holyoke College in South Hadley, MA on 8-13 July 2007. This unique interdisciplinary meeting includes astronomers and astrophysicists interested in star and planet formation, planetary scientists and meteoriticists interested in the early history of the Solar System, and plasma and life scientists. This meeting is much broader than most conferences and many fruitful research collaborations have been initiated at Gordon conferences, encouraged by the relaxed pace of the meeting.

Information on the meeting, registration, etc. is available at
http://www.grc.org/programs.aspx?year=2007&program=origins .

Speakers and discussion leaders include Yuri Aikawa, Sean Andrews, David Bennett, Ted Bergin, Martin Bizzarro, Alan Boss, Fred Ciesla, Harold Connolly, Marianna Cosarinsky, Andrew Davis, Suzan Edwards, Elise Furlan, Charles Gammie, Matthieu Gounelle, Lynne Hillenbrand, Rhian Jones, Scott Kenyon, Zoe Leinhardt, Doug Lin, James Lyons, Michael Meyer, Amaya Moro-Martin, Frank Podosek, Ken Rice, Scott Sandford, Sara Seager, Meenakshi Wadhwa, Dan Watson, Ed Young, and Michael Zolensky.

The Chair and Vice-Chair of the 2007 Origins of Solar Systems conference are Lee Hartmann (Michigan) and Sara Russell (Natural History Museum, London). Some money from NASA may be available to assist students and postdocs with travel cost offsets.