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Abstracts of recently accepted papers

Keck Interferometer observations of classical and weak line T Tauri stars

R.L. Akeson[1], A.F. Boden[1], J.D. Monnier[2], R. Millan-Gabet[1], C. Beichman[1], J. Beletic[3], N. Calvet[4], L. Hartmann[4], L. Hillenbrand[5], C. Koresko[1], A. Sargent[5], and A. Tannirkulam[2]

[1]Michelson Science Center, California Institute of Technology , MS 100-22, Pasadena, CA, 91125, USA
[2]Univ. of Michigan, 941 Dennison Bldg, Ann Arbor, MI, 48109, USA
[3]W.M.Keck Observatory, California Association for Research in Astronomy , 65-1120 Mamalahoa Hwy., Kamuela, HI 96743, USA
[4]Smithsonian Astrophysical Observatory, Mail Stop 42, Cambridge, MA 021 38, USA
[5]Dept of Astronomy, California Institute of Technology, MS 105-24, Pasa dena, CA, 91125, USA

E-mail contact: rla@ipac.caltech.edu

We present observations of the T Tauri stars BP Tau, DG Tau, DI Tau, GM Aur, LkCa 15, RW Aur and V830 Tau, using long baseline infrared interferometry at K band (2.2 μm) from the Keck Interferometer. The target sources have a range of mass accretion rates and excess near-infrared emission. The interferometer is most sensitive to extended emission on characteristic size scales of 1 to 5 millarcseconds. All sources show evidence for resolved K band emission on these scales, although a few of the sources are marginally consistent with being unresolved. We calculate the infrared excess based on fitting stellar photosphere models to the optical photometry and estimate the physical size of the emission region using simple geometric models for the sources with a significant infrared excess. Assuming that the K band resolved emission traces the inner edge of the dust disk, we compare the measured characteristic sizes to predicted dust sublimation radii and find that the models require a range of dust sublimation temperatures and possibly optical depths within the inner rim to match the measured radii.

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Preprint available at http://spider.ipac.caltech.edu/staff/rla/

Pulsations and metallicity of the pre-main sequence eclipsing spectroscopic binary RS Cha

Evelyne Alecian[1], Claude Catala[1], Claude Van't Veer-Menneret[2], Marie-Jo Goupil[1] and Luis Balona[3]

[1] Observatoire de Paris-Meudon, LESIA, 5 place Jules Jansen, 92195 Meudon, France
[2] Observatoire de Paris-Meudon, GEPI, 5 place Jules Jansen, 92195 Meudon, France
[3] SAAO, P.O. Box 9, Observatory 7935, Cape, South Africa

E-mail contact: evelyne.alecian@obspm.fr

We present new spectroscopic observations of the pre-main sequence eclipsing spectroscopic binary RS Cha. A sample of 174 spectra were obtained with the GIRAFFE spectrograph at the SAAO at 32000 resolution. The radial velocity curves derived from these spectra were combined with previous observations spanning a period of about 30 years to correct the ephemeris of the system, and the result indicates that the orbital period is not constant.

Residuals of the binary radial velocity curve for both components with amplitudes up to a few km.s^{-1} and periods on the order of 1 hr are clearly seen in our data, which we interpret as the signatures of delta-Scuti type pulsations.

We revisited the masses of both components and determined the surface metallicity Z of both components of the RS Cha system by fitting synthetic spectra to observed spectra in a set of selected spectral regions. The synthetic spectra are calculated with

the SYNTH code using stellar atmosphere models computed with the Kurucz ATLAS 9 code, along with a list of lines obtained from the VALD database. A selection of the best spectra and the most relevant spectral regions allowed us to determine $Z = 0.028 \pm 0.005$. We also derived new values of $v \sin i$: 64 ± 6 km/s and 70 ± 6 km/s for the primary and the secondary star, respectively. Finally, we observationally confirm that the RS Cha system is a synchronized and circularized system.

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http://www.solaire.obspm.fr/soluminaire/rscha.pdf

SIMBA observations of the Keyhole Nebula

Kate J. Brooks[1], Guido Garay[2], Markus Nielbock[3], Nathan Smith[4] and Pierre Cox[5]

[1] Australia Telescope National Facility, P.O. Box 76, Epping NSW 1710, Australia
[2] Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago 19, Chile
[3] Astronomisches Institut der Ruhr-Universitat Bochum, Universitatsstrasse 150, D-44780 Bochum, Germany
[4] Center for Astrophysics and Space Astronomy, University of Colorado, 389 UCB, Boulder CO80309
[5] Institut de RadioAstronomie Millimetrique, 300 rue de la Piscine, Domaine Universitaire, 38406 Saint Martin dHeres, France

E-mail contact: Kate.Brooks@csiro.au

We report observations made with the SIMBA bolometer at SEST to measure the 1.2-mm continuum emission towards the Keyhole nebula. We have detected 1.2-mm emission towards the ionized gas filaments of the Car II radio source that is attributed to thermal free-free emission. Several compact 1.2-mm emission sources have also been identified and found to correspond to bright-rimmed molecular globules. Under the assumption that for these sources the 1.2-mm emission corresponds to dust, we find mass estimates in the range 3 to 19 $M_\odot$, which are consistent with previous molecular-line measurements. The data also yield new 1.2-mm flux measurements at two different epochs during the cyclic brightness variation of Eta Carinae. No emission was detected towards the trademark dark keyhole of the nebula, consistent with it being cool molecular gas situated at the outskirts of the H II region.

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http://www.atnf.csiro.au/people/kbrooks/html/publications.html

Discovery of deuterated water in a young proto-planetary disk

Cecilia Ceccarelli[1], Carsten Dominik[2], Emmanuel Caux[3], Bertrand Lefloch[1] and Paola Caselli[4]

[1] Laboratoire d'Astrophysique, Observatoire de Grenoble - BP 53, F-38041 Grenoble cedex 09, France
[2] Astronomical Inst. "Anton Pannekoek", Univ. of Amsterdam, Kruislaan 403, NL-1098SJ Amsterdam, The Netherlands
[3] CESR CNRS-UPS, BP 4346, 31028 - Toulouse cedex 04, France
[4] INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

E-mail contact: Cecilia.Ceccarelli@obs.ujf-grenoble.fr

We report the first detection of the ground transition of the deuterated water at 464 GHz in the young proto-planetary disk surrounding the solar type protostar DM Tau. The line is observed in absorption against the continuum from the cold dust in the disk midplane, with a line to continuum ratio close to unity. The observation implies that deuterated gaseous water is present, with a relatively large abundance ($\sim 3 \times 10^{-9}$), in the outer disk above the midplane, where the density is, within a factor ten, $\sim 10^6$ cm^{-3} and the temperature is lower than about 25 K. In these conditions, the H_2O condensation timescale is much smaller than the DM Tau disk age, and, therefore, water should be fully frozen onto the grain mantles. We suggest that UV photons and/or X-rays sublimate part of the mantles re-injecting the ices into the gas phase. Even though there is currently no measurement of H_2O, we provide arguments that the HDO/H_2O ratio should be about 0.01 or larger, which would be hundreds of times larger than the values measured in Solar System objects. This suggests the need of strong caution in comparing and linking the HDO/H_2O in Solar System and star forming environments.

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http://www-laog.obs.ujf-grenoble.fr/Recherche/AstrophysiqueMoleculaire/membres.php

Chandra X-ray observations of the stellar group near the Herbig Be star MWC 297.

A revision of the X-ray properties of MWC 297

F. Damiani[1], **G. Micela**[1] **and S. Sciortino**[1]

[1] INAF - Osservatorio Astronomico di Palermo G.S.Vaiana,Piazza del Parlamento 1, I-90134 Palermo, Italy

E-mail contact: damiani@astropa.unipa.it

We present a *Chandra* ACIS-I X-ray observation of the region near the Herbig early-Be star MWC 297, where we detect a tight group of point X-ray sources. These are probably physically associated to MWC 297, because of their obvious clustering with respect to the more scattered field-source population. These data are compared to earlier ASCA data with much poorer spatial resolution, from which the detection of strong quiescent and flaring emission from MWC 297 itself was claimed. We argue that this star, contributing only 5% to the total X-ray emission of the group, was probably not the dominant contributor to the observed ASCA emission, while the X-ray brightest star in the group is a much better candidate. This is also supported by the spectral analysis of the *Chandra* data, with reference to the ASCA spectra. We conclude that none of the X-ray data available for MWC 297 justify the earlier claim of strong magnetic activity in this star. The X-ray emission of MWC 297 during the *Chandra* observation is even weaker than that found in other Herbig stars with the same spectral type, even accounting for its large line-of-sight absorption.

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http://www.astropa.unipa.it/Library/OAPA_preprints/mwc297.ps.gz

Observations and Modeling of the 2–25 μm Emission From High Mass Protostellar Object Candidates

James M. De Buizer[1], **Mayra Osorio**[2] **and Nuria Calvet**[3]

[1] Gemini Observatory, Casilla 603, La Serena, Chile
[2] Instituto de Astrofísica de Andalucía, CSIC, Camino Bajo de Huétor 50, E-18008 Granada, Spain
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: jdebuizer@gemini.edu

This is a report on detailed modeling of young high-mass protostellar candidates during their most embedded and obscured phases. We performed narrowband mid-infrared imaging of three candidate high-mass protostellar objects in G11.94-0.62, G29.96-0.02, and G45.07+0.13 at Gemini Observatory using the Thermal-Region Camera and Spectrograph (T-ReCS). The sources were imaged through up to 11 narrowband filters, sampling their SEDs over the entire 2–25 μm infrared range. For the first time, we have fit the observed SEDs of massive protostars with models that take into account departures from spherical symmetry in the infalling envelopes. In this way, we have been able to back out of the models detailed physical parameters for these earliest stages of massive stellar life. Our detailed modeling suggests that massive star formation can proceed in a way very similar to the formation of low-mass stars.

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http://www.ctio.noao.edu/~debuizer/

Constraining the Evolutionary Stage of Class I Protostars: Multi-wavelength Observations and Modeling

J.A. Eisner[1,2], **L.A. Hillenbrand**[1], **John M. Carpenter**[1], **& S. Wolf**[3]

[1] California Institute of Technology, Department of Astronomy MC 105-24, Pasadena, CA 91125, USA
[2] Current Address: Department of Astronomy, 601 Campbell Hall, University of California at Berkeley, Berkeley, CA 94720, USA
[3] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117, Heidelberg, Germany

E-mail contact: jae@astron.berkeley.edu

We present new Keck images at 0.9 μm and OVRO 1.3 mm continuum images of five Class I protostars in the Taurus star forming region. We analyze these data in conjunction with broadband spectral energy distributions and 8-13 μm spectra from the literature using a Monte Carlo radiative transfer code. By fitting models for the circumstellar dust distributions simultaneously to the scattered light images, millimeter continuum data, and the SEDs, we attempt to distinguish between flared disks, infalling envelopes with outflow cavities, and combinations of disks and envelopes. For each of these circumstellar density distributions,

we generate grids of models for varying geometries, dust masses, and accretion rates, and determine the best fits by minimizing the residuals between model and data. Comparison of the residuals for best-fit disk, envelope, and disk+envelope models demonstrates that in general, models incorporating *both* massive envelopes and massive embedded disks fit the imaging+SED data best. The implied envelope infall rates for these disk+envelope models are generally consistent with infall rates derived by previous investigators, although they are approximately an order of magnitude larger than inner disk accretion rates inferred from recent spectroscopic measurements. In addition, the disk masses inferred from our models are close to or larger than the limit for gravitationally stable disks, indicating that Class I disks may undergo periodic episodes of enhanced accretion, perhaps as a result of gravitational instabilities. An important caveat to these results is that in some cases, no single model can fit all of the imaging and SED data well, suggesting that further refinements to models of the circumstellar dust distributions around Class I sources are necessary. We discuss several potential improvements to the models, as well as new constraints that will become available with upcoming millimeter and infrared facilities.

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http://xxx.lanl.gov/abs/astro-ph/0508380

Radio and X-ray variability of Young Stellar Objects in the Coronet cluster

Jan Forbrich[1,2], Thomas Preibisch[1] and Karl M. Menten[1]

[1] MPI für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[2] Astrophysikalisches Institut und Universitäts-Sternwarte Jena, Schillergäßchen 2-3, D-07740 Jena, Germany

E-mail contact: forbrich@mpifr-bonn.mpg.de

The Coronet Cluster in the nearby R CrA dark cloud offers the rare opportunity to study at least four ”class I” protostellar sources as well as one candidate ”class 0” source, a Herbig Ae star, and a candidate brown dwarf within a few square arcminutes - most of them detected at radio- and X-ray wavelengths. These sources were observed with the Very Large Array (VLA) at 3.5cm on nine occasions in 1998, spread over nearly four months. The source IRS 5, earlier shown to emit circularly polarized radio emission, was observed to undergo a flux increase accompanied by changes in its polarization properties. Comparison with VLA measurements taken in January 1997 allows for some analysis of longer-term variability. In addition to this radio monitoring, we analyze archival Chandra and XMM-Newton X-ray data of these sources. Three class I protostars are bright enough for X-ray spectroscopy, and we perform a variability analysis for these sources, covering a total of 154 ksec spread over more than two and a half years. Also in X-rays, IRS 5 shows the most pronounced variability, whilst the other two class I protostars IRS 1 and IRS 2 have more stable emission. X-ray data is also analyzed for the recently identified candidate class 0 source IRS 7E, which shows strong variability as well as for the Herbig Ae star R CrA for which we find extremely hot X-ray-emitting plasma. For IRS 1,2 and 5, the hydrogen column densities derived from the X-ray spectra are at about half the values derived with near-infrared techniques, a situation similar to what has been observed towards some other young stellar objects.

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Numerical simulations of type I planetary migration in nonturbulent magnetized discs

Sebastien Fromang[1], Caroline Terquem[2,3] and Richard P. Nelson[1]

[1] Astronomy Unit, Queen Mary, University of London, Mile End Road, London E1 4NS, UK
[2] Institut d’Astrophysique de Paris, UMR7095 CNRS, Université Pierre & Marie Curie–Paris 6, 98bis boulevard Arago, 75014 Paris, France
[3] Université Denis Diderot–Paris 7, 2 Place Jussieu, 75251 Paris Cedex 5, France

E-mail contact: s.fromang@qmul.maths.ac.uk

Using 2D MHD numerical simulations performed with two different finite difference Eulerian codes, we analyze the effect that a toroidal magnetic field has on low mass planet migration in nonturbulent protoplanetary discs. The presence of the magnetic field modifies the waves that can propagate in the disc. In agreement with a recent linear analysis (Terquem 2003), we find that two magnetic resonances develop on both sides of the planet orbit, which contribute to a significant global torque. In order to measure the torque exerted by the disc on the planet, we perform simulations in which the latter is either fixed on a circular orbit or allowed to migrate. For a 5 earth mass planet, when the ratio β between the square of the sound speed and that of the Alfven speed at the location of the planet is equal to 2, we find inward migration when the magnetic field B_ϕ is uniform in the disc,

reduced migration when B_ϕ decreases as r^{-1} and outward migration when B_ϕ decreases as r^{-2}. These results are in agreement with predictions from the linear analysis. Taken as a whole, our results confirm that even a subthermal stable field can stop inward migration of an earth–like planet.

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http://www.maths.qmul.ac.uk/~rpn/preprints/

Deep Near-Infrared Observations of L1014: Revealing the Nature of the Core and its Embedded Source

T.L. Huard[1], P.C. Myers[1], D.C. Murphy[2], L.J. Crews[3], C.J. Lada[1], T.L. Bourke[1], A. Crapsi[4], N.J. Evans II[5], D.W. McCarthy[6] and C. Kulesa[6]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA
[2] Carnegie Institution of Washington, 813 Santa Barbara St., Pasadena, CA 91101, USA
[3] University of Tennessee at Martin, Martin, TN 38238, USA
[4] Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy
[5] University of Texas at Austin, 1 University Station C1400, Austin, TX 78712, USA
[6] Steward Observatory, University of Arizona, 933 North Cherry Ave., Tucson, AZ 85721, USA

E-mail contact: thuard@cfa.harvard.edu

Recently, the Spitzer Space Telescope discovered L 1014-IRS, a mid-infrared source with protostellar colors, toward the heretofore "starless" core L 1014. We present deep near-infrared observations that show a scattered light nebula extending from L 1014-IRS. This nebula resembles those typically associated with protostars and young stellar objects, tracing envelope cavities presumably evacuated by an outflow. The northern lobe of the nebula has an opening angle of ~100°, while the southern lobe is barely detected. Its morphology suggests that the bipolar cavity and inferred protostellar disk is not inclined more than 30° from an edge-on orientation. The nebula extends at least 8″ from the source at K_s, strongly suggesting that L 1014-IRS is embedded within L 1014 at a distance of 200 pc rather than in a more distant cloud associated with the Perseus arm at 2.6 kpc. In this case, the apparently low luminosity of L 1014-IRS, 0.090 $L_\odot$, is consistent with it having a substellar mass. However, if L 1014-IRS is obscured by a circumstellar disk, its luminosity and inferred mass may be greater. Using near-infrared colors of background stars, we investigate characteristics of the L 1014 molecular cloud core. We determine a mass of 5.7 $M_\odot$ for regions of the core with $A_V \geq 2$ magnitudes. A comparison of the radial extinction profile of L 1014 with other cores suggests that L 1014 may be among the most centrally condensed cores known, perhaps indicative of the earliest stages of brown dwarf or star formation processes.

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Preprints available at http://arxiv.org/abs/astro-ph/0509302 or http://cfa-www.harvard.edu/~thuard

Radial velocity survey for planets and brown dwarf companions to very young brown dwarfs and very low-mass stars in Cha I with UVES at the VLT

V. Joergens[1,2]

[1] Leiden Observatory / Sterrewacht Leiden, P.O.Box 9513, 2300 RA Leiden, Netherlands
[2] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, D-85748 Garching, Germany

E-mail contact: viki@strw.leidenuniv.nl

We present results of a radial velocity (RV) survey for planets and brown dwarf companions to very young brown dwarfs and (very) low-mass stars in the Cha I star forming cloud. Time-resolved high-resolution echelle spectra have been taken with UVES at the VLT between 2000 and 2004 of Cha Hα 1–8 and Cha Hα 12 (M6–M8), B34 (M5), CHXR 74 (M4.5) and Sz 23 (M2.5). The achieved precision of the relative RVs range between 40 and 670 m/s and is sufficient to detect Jupitermass planets around the targets. This is the first RV survey of very young brown dwarfs and it probes multiplicity, which is a key parameter for formation in an as yet unexplored domain in terms of age, mass and orbital separation. We find that on time scales of 40 days and less the subsample of ten brown dwarfs and very low-mass stars ($M \leq 0.12\,M_\odot$, spectral types M5–M8) has constant RVs. Estimates for upper limits for masses of hypothetical companions for them range between $0.1\,M_{Jup}$ and $1.5\,M_{Jup}$ for assumed orbital separations of 0.1 AU. This hints at a rather small multiplicity fraction for very young brown dwarfs and very low-mass stars for orbital separations of ≤0.1 AU and orbital periods of ≤40 days. Furthermore, the non-variable objects demonstrate

the lack of any significant RV noise due to stellar activity down to the precision necessary to detect giant planets. Thus, very young brown dwarfs and very low-mass stars are suitable targets for searches for RV planets. Three objects of the sample exhibit significant RV variations with peak-to-peak RV differences of 2–3 $\mathrm{km\,s^{-1}}$. For the highest mass object observed with UVES (Sz 23, ~0.3 $\mathrm{M_\odot}$), the variations are on time scales of days and might be explained by rotational modulation. On the other hand, the brown dwarf candidate Cha Hα 8 (M6.5) and the low-mass star CHXR 74 (M4.5) display significant RV variations on times scales of $\geq$ 150 days, while they are both RV constant or show only much smaller amplitude variations on time scales of days to weeks, i.e. on time scales of the rotation periods. A suggested explanation for the detected RV variations of CHXR 74 and Cha Hα 8 are giant planets or very low-mass brown dwarfs of at least a few Jupiter masses orbiting with periods of several months or longer. Thus, the presented RV data indicate that orbital periods of companions to very young brown dwarfs and (very) low-mass stars are possibly several months or longer and orbital separations $\geq$ 0.2 AU. This parameter range has not been covered for all targets yet but will be probed by follow-up observations. Furthermore, we show that the scaled down equivalent to the brown dwarf desert found around solar-like stars would be a 'giant planet desert' around brown dwarf and very low-mass star primaries if formed by the same mechanism. The present data test its existence for the targets in the limited separation range of the survey. So far, no hints for companions in a 'giant planet desert' have been found.

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http://www.strw.leidenuniv.nl/~viki

http://xxx.uni-augsburg.de/abs/astro-ph/0509134

Improved kinematics for brown dwarfs and very low-mass stars in Cha I and a discussion of brown dwarf formation

V. Joergens[1]

[1] Leiden Observatory / Sterrewacht Leiden, P.O.Box 9513, 2300 RA Leiden, Netherlands

E-mail contact: viki@strw.leidenuniv.nl

We present a precise kinematic study of very young brown dwarfs in the Cha I cloud based on radial velocities (RVs) measured with UVES at the VLT. The kinematics of the brown dwarfs in Cha I are compared to the kinematics of T Tauri stars in the same field based on UVES measurements for very low-mass ones and based on RVs from the literature. In comparison with a former paper (Joergens & Guenther 2001), additional UVES spectra have been taken, the reduction of the spectra was improved and a re-study of the literature for RVs of T Tauri stars in Cha I lead to a cleaned and enlarged sample for the T Tauri stars. The result is an improved empirical RV distribution of the brown dwarfs as well as of the T Tauri stars in Cha I. We find that the RVs of the studied nine brown dwarfs and very low-mass stars (M6–M8) in ChaI have a mean value of 15.7 $\mathrm{km\,s^{-1}}$, a dispersion measured in terms of standard deviation of 0.9 $\mathrm{km\,s^{-1}}$, and they cover a total range of 2.6 $\mathrm{km\,s^{-1}}$. The standard deviation is consistent with the dispersion measured in terms of fwhm of 2.1 $\mathrm{km\,s^{-1}}$ by Joergens & Guenther (2001). The studied sample of 25 T Tauri stars (G2–M5) has a mean RV of 14.7 $\mathrm{km\,s^{-1}}$, a dispersion in terms of standard deviation of 1.3 $\mathrm{km\,s^{-1}}$ and in terms of fwhm of 3.0 $\mathrm{km\,s^{-1}}$ and a total range of 4.5 $\mathrm{km\,s^{-1}}$. The RV dispersion of the brown dwarfs is consistent within the errors with that of the T Tauri stars, which is in line with the finding of no mass dependence in some theoretical models of the ejection-scenario for the formation of brown dwarfs. In contrast to current N-body simulations, we do not find a high-velocity tail for the brown dwarfs RVs. We find suggestive hints for different kinematics of binaries compared to predominantly single objects in Cha I, as suggested by some models. The global RV dispersion for Cha I members (1.24 $\mathrm{km\,s^{-1}}$) is significantly lower than for Taurus members (2.0 $\mathrm{km\,s^{-1}}$), despite a larger stellar density in Cha I showing that a fundamental increase of velocity dispersion with stellar density of the star forming region is observationally not established. The observed RVs of brown dwarfs in Cha I are less dispersed than predicted by any of the models for the ejection-scenario.

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http://www.strw.leidenuniv.nl/~viki

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Dust diffusion in protoplanetary discs by magnetorotational turbulence

Anders Johansen[1] **and Hubert Klahr**[1]

[1] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

E-mail contact: johansen@mpia.de

We measure the turbulent diffusion coefficient of dust grains embedded in magnetorotational turbulence in a protoplanetary disc directly from numerical simulations and compare it to the turbulent viscosity of the flow. The simulations are done in a local coordinate frame comoving with the gas in Keplerian rotation. Periodic boundary conditions are used in all directions, and vertical gravity is not applied to the gas. Using a two-fluid approach, small dust grains of various sizes (with friction times up to $\Omega_0\tau_{\rm f} = 0.02$) are allowed to move under the influence of friction with the turbulent gas. We measure the turbulent diffusion coefficient of the dust grains by applying an external sinusoidal force field acting in the vertical direction on the dust component only. This concentrates the dust around the mid-plane of the disc, and an equilibrium distribution of the dust density is achieved when the vertical settling is counteracted by the turbulent diffusion away from the mid-plane. Comparing with analytical expressions for the equilibrium concentration we deduce the vertical turbulent diffusion coefficient. The vertical diffusion coefficient is found to be lower than the turbulent viscosity and to have an associated vertical diffusion Prandtl number of about 1.5. A similar radial force field also allows us to measure the radial turbulent diffusion coefficient. We find a radial diffusion Prandtl number of about 0.85 and also find that the radial turbulent diffusion coefficient is around 70% higher than the vertical. As most angular momentum transport happens through magnetic Maxwell stresses, both the vertical and the radial diffusion coefficients are found to be significantly higher than suggested by the angular momentum transport by Reynolds stresses alone. We also find evidence for trapping of dust grains of intermediate friction time in turbulent eddies.

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Gravoturbulent formation of planetesimals

Anders Johansen[1], Hubert Klahr[1] and Thomas Henning[1]

[1] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

E-mail contact: johansen@mpia.de

We explore the effect of magnetorotational turbulence on the dynamics and concentrations of boulders in local box simulations of a sub-Keplerian protoplanetary disc. The solids are treated as particles each with an independent space coordinate and velocity. We find that the turbulence has two effects on the solids. 1) Meter and decameter bodies are strongly concentrated, locally up to a factor 100 times the average dust density, whereas decimeter bodies only experience a moderate density increase. The concentrations are located in large scale radial gas density enhancements that arise from a combination of turbulence and shear. 2) For meter-sized boulders, the concentrations cause the average radial drift speed to be reduced by 40%. We find that the densest clumps of solids are gravitationally unstable under physically reasonable values for the gas column density and for the dust-to-gas ratio due to sedimentation. We speculate that planetesimals can form in a dust layer that is not in itself dense enough to undergo gravitational fragmentation, and that fragmentation happens in turbulent density fluctuations in this sublayer.

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Protostellar holes: Spitzer Space Telescope observations of the protostellar binary IRAS 16293-2422

Jes K. Jørgensen[1], Fred Lahuis[2,3], Fredrik L. Schöier[4], Ewine F. van Dishoeck[2], Geoffrey A. Blake[5], A. C. Adwin Boogert[6], Cornelis P. Dullemond[7], Neal J. Evans II[8], Jacqueline E. Kessler-Silacci[8], and Klaus M. Pontoppidan[2]

[1]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS42, Cambridge, MA 02138, USA
[2]Leiden Observatory, PO Box 9513, 2300 RA Leiden, The Netherlands
[3]SRON National Institute for Space Research, PO Box 800, 9700 AV Groningen, The Netherlands
[4]Stockholm Observatory, AlbaNova, 106 91 Stockholm, Sweden
[5]Div. of Geological and Planetary Sciences, Mail Code 150-21, California Inst. of Technology, Pasadena, CA 91125, USA
[6]Div. of Physics, Mathematics and Astronomy, Mail Code 150-24, California Inst. of Technology, Pasadena, CA 91125, USA
[7]Max Planck Institut für Astronomie, Koenigstuhl 17, 69117 Heidelberg, Germany
[8]Department of Astronomy, University of Texas at Austin, 1 University Station, C1400, Austin, TX 78712, USA

E-mail contact: jjorgensen@cfa.harvard.edu

Mid-infrared (23–35 μm) emission from the deeply embedded "Class 0" protostar IRAS 16293-2422 is detected with the Spitzer

Space Telescope infrared spectrograph. A detailed radiative transfer model reproducing the full spectral energy distribution (SED) from 23 μm to 1.3 mm requires a large inner cavity of radius 600 AU in the envelope to avoid quenching the emission from the central sources. This is consistent with a previous suggestion based on high angular resolution millimeter interferometric data. An alternative interpretation using a 2D model of the envelope with an outflow cavity can reproduce the SED but not the interferometer visibilities. The cavity size is comparable to the centrifugal radius of the envelope and therefore appears to be a natural consequence of the rotation of the protostellar core, which has also caused the fragmentation leading to the central protostellar binary. With a large cavity such as required by the data, the average temperature at a given radius does not increase above 60–80 K and although hot spots with higher temperatures may be present close to each protostar, these constitute a small fraction of the material in the inner envelope. The proposed cavity will also have consequences for the interpretation of molecular line data, especially of complex species probing high temperatures in the inner regions of the envelope.

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The detection of Class I methanol masers towards regions of low-mass star formation.

S.V. Kalenskii[1], V.G. Promyslov[1], V.I. Slysh[1], P. Bergman[2] and A. Winnberg[2]

[1] Astro Space Center of P.N. Lebedev's Physical Institute, 117997 Moscow, Russia
[2] Onsala Space Observatory, SE-439 92 Onsala, Sweden

E-mail contact: kalensky@asc.rssi.ru

Six young bipolar outflows in regions of low-to-intermediate-mass star formation were observed in the $7_0 - 6_1A^+$, $8_0 - 7_1A^+$, and $5_{-1} - 4_0E$ methanol lines at 44, 95, and 84 GHz, respectively. Narrow features were detected towards NGC 1333IRAS4A, HH 25MMS, and L1157 B1. Flux densities of the detected lines are no higher than 11 Jy, which is much lower than the flux densities of strong maser lines in regions of high-mass star formation. Analysis shows that most likely the narrow features are masers.

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Near Infrared Imaging Survey of Bok Globules: Density Structure

Ryo Kandori[1,2], Yasushi Nakajima[2], Motohide Tamura[2], Ken'ichi Tatematsu[2], Yuri Aikawa[3], Takahiro Naoi[4], Koji Sugitani[5], Hidehiko Nakaya[6], Takahiro Nagayama[7], Tetsuya Nagata[7], Mikio Kurita[8], Daisuke Kato[8], Chie Nagashima[8], and Shuji Sato[8]

[1] Department of Astronomical Science, Graduate University for Advanced Studies (Sokendai), 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[2] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[3] Department of Earth and Planetary Sciences, Kobe University, Kobe 657-8501, Japan
[4] Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan
[5] Institute of Natural Sciences, Nagoya City University, Mizuho-ku, Nagoya 467-8501, Japan
[6] Subaru Telescope, National Astronomical Observatory of Japan, 650 North Aóhoku Place, Hilo, HI 96720, USA
[7] Department of Astronomy, Kyoto University, Kyoto 606-8502, Japan
[8] Department of Astrophysics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

E-mail: kandori@optik.mtk.nao.ac.jp

On the basis of near-infrared imaging observations, we derived visual extinction (A_V) distribution toward ten Bok globules through measurements of both the color excess (E_{H-K}) and the stellar density at J, H, and K_s (star count). Radial column density profiles for each globule were analyzed with the Bonnor-Ebert sphere model. Using the data of our ten globules and four globules in the literature, we investigated the stability of globules on the basis of $\xi_{\max}$, which characterizes the Bonnor-Ebert sphere as well as the stability of the equilibrium state against the gravitational collapse. We found that more than half of starless globules are located near the critical state ($\xi_{\max} = 6.5 \pm 2$). Thus, we suggest that a nearly critical Bonnor-Ebert sphere characterizes the typical density structure of starless globules. Remaining starless globules show clearly unstable states ($\xi_{\max} > 10$). Since unstable equilibrium states are not long maintained, we expect that these globules are on the way to gravitational collapse or

that they are stabilized by non-thermal support. It was also found that all the star-forming globules show unstable solutions of $\xi_{\rm max} > 10$, which is consistent with the fact that they have started gravitational collapse. We investigated the evolution of a collapsing gas sphere whose initial condition is a nearly critical Bonnor-Ebert sphere. We found that the column density profiles of the collapsing sphere mimic those of the static Bonnor-Ebert spheres in unstable equilibrium. The collapsing gas sphere resembles marginally unstable Bonnor-Ebert spheres for a long time. We found that the frequency distribution of $\xi_{\rm max}$ for the observed starless globules is consistent with that from model calculations of the collapsing sphere. In addition to the near-infrared observations, we carried out radio molecular line observations ($C^{18}O$ and N_2H^+) toward the same ten globules. We confirmed that most of the globules are dominated by thermal support. The line width of each globule was used to estimate the cloud temperature including the contribution from turbulence, with which we estimated the distance to the globules from the Bonnor-Ebert model fitting.

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A Millimeter Continuum Survey for Massive Protoclusters in the Outer Galaxy

R. Klein[1,3], B. Posselt[2,3], K. Schreyer[2], J. Forbrich[4,2] and Th. Henning[5]

[1] University of California at Berkeley, 366 Le Conte Hall, Berkeley, CA 94720-7300, USA
[2] Astrophysikalisches Institut und Universitaets-Sternwarte Jena, Schillergaesschen 2-3, D 07745 Jena, Germany
[3] Max-Planck-Institut fuer extraterrestrische Physik, Giessenbachstr., D-85748 Garching, Germany
[4] Max-Planck-Institut fuer Radioastronomie, Auf dem Huegel 69, D-53121 Bonn, Germany
[5] Max-Planck-Institut fuer Astronomie, Koenigstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: klein@calmail.berkeley.edu

Our search for the earliest stages of massive star formation turned up twelve massive pre-protocluster candidates plus a few protoclusters. For this search, we selected 47 FIR-bright IRAS sources in the outer Galaxy. We mapped regions of several square arcminutes around the IRAS source in the millimeter continuum in order to find massive cold cloud cores possibly being in a very early stage of massive star formation. Masses and densities are derived for the 128 molecular cloud cores found in the obtained maps. We present these maps together with near-infrared, mid-infrared, and radio data collected from the 2MASS, MSX, and NVSS catalogs. Further data from the literature on detections of high-density tracers, outflows, and masers are added. The multi-wavelength datasets are used to characterize each observed region. The massive cloud cores ($M > 100 M_\odot$) are placed in a tentative evolutionary sequence depending on their emission at the investigated wavelengths. Candidates for the youngest stages of massive star formation are identified by the lack of detections in the above-mentioned near-infrared, mid-infrared, and radio surveys. Twelve massive cores prominent in the millimeter continuum fulfill this requirement. Since neither FIR nor radio emission have been detected from these cloud cores massive protostars must be very deeply embedded in these cores. Some of these objects may actually Pre-Proto-cluster cores: an up to now rare object class, where the initial conditions of massive star formation can be studied.

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Stellar Winds and Embedded Star Formation in the Galactic Center Quintuplet and Arches Clusters: Multifrequency Radio Observations

Cornelia C. Lang[1], Kelsey E. Johnson[2], W. M. Goss[3] and Luis F. Rodríguez[4]

[1] Dept. of Physics & Astronomy, University of Iowa, Iowa City, IA 52245 USA
[2] Dept. of Astronomy, University of Virginia, Charlottesville, VA 22903, USA
[3] NRAO, PO Box 0, Socorro NM 87801, USA
[4] Centro de Radioastronomía y Astrofísica, UNAM, Campus Morelia, Apdo. Postal 3-72, Morelia, Michoacán 58089, México

E-mail contact: cornelia-lang@uiowa.edu

A multi-frequency, multi-configuration study has been made of the compact radio sources in the Galactic Center Quintuplet and Arches stellar clusters using the Very Large Array. Ten radio sources have been detected in the Quintuplet cluster. The majority of these radio sources have rising spectral indices and are positionally coincident with young massive stars that are known to have powerful stellar winds. We conclude that the three most compact of these sources are produced by stellar wind emission;

thus, mass-loss rates can be derived and have an average value of 3×10^{-5} $M_\odot$ yr^{-1}. The remainder of the sources are likely to be a combination of stellar wind emission and free-free emission from surrounding ionized gas. In three cases, the radio sources have no stellar counterpart and the radio emission is thought to arise from compact or ultra-compact HII regions. If so, these sources would be the first detections of embedded massive stars to be discovered in the Galactic center clusters. The radio nebula associated with the Pistol star resembles the nebula surrounding the LBV star η Carina and may be related to the stellar wind of the Pistol star. Ten compact radio sources are detected in the Arches cluster and are interpreted to be stellar wind sources, consistent with previous findings. Several of the sources show moderate variability (10-30%) in their flux density, possibly related to a nonthermal component in the wind emission. A number of radio sources in both clusters have X-ray counterparts, which have been interpreted to be the shocked, colliding winds of massive binary systems.

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Very low-mass members of the Lupus 3 cloud

Belén López Martí[1], **Jochen Eislöffel**[2] **and Reinhard Mundt**[3]

[1] Dep. d'Astronomia i Astrofísica, Universitat de Barcelona, Martí i Franquès 1, E-08028 Barcelona, Spain
[2] Thüringer Landessternwarte, Sternwarte 5, D-07778 Tautenburg, Germany
[3] Max Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: blopez@am.ub.es

We report on a multi-band survey for very low-mass stars and brown dwarfs in the Lupus 3 cloud with the Wide Field Imager (WFI) at the ESO/MPG 2.2 m telescope on La Silla Observatory (Chile). Our multiband optical photometry is combined with available 2MASS *JHK* photometry to identify 19 new young stars and 3 brown dwarf candidates as probable members of this star forming region. Our objects are mostly clustered around the cloud core. Stars and brown dwarfs have similar levels of Hα emission, probably a signature of accretion. One object, a brown dwarf candidate, exhibits a near-infrared excess, which may indicate the presence of a disk, but its Hα emission cannot be confirmed due to its faintness in the optical passbands. We also find two visual pairs of probable Lupus 3 members that may be wide binaries.

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A Moving Cluster Distance to the Exoplanet 2M1207 B in the TW Hya Association

Eric E. Mamajek[1]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS-42, Cambridge, MA, 02138, USA

E-mail contact: emamajek@cfa.harvard.edu

A candidate extrasolar planet companion to the young brown dwarf 2MASSW J1207334-393254 (2M1207) was recently discovered by Chauvin et al. They find that 2M1207 B's temperature and luminosity are consistent with being a young, ~5 M_{Jup} planet. The 2M1207 system is purported to be a member of the TW Hya association (TWA), and situated ~70 pc away. Using a revised space motion vector for TWA, and improved proper motion for 2M1207, I use the moving cluster method to estimate the distance to the 2M1207 system and other TWA members. The derived distance for 2M1207 (53 ± 6 pc) forces the brown dwarf and planet to be half as luminous as previously thought. The inferred masses for 2M 1207 A and B decrease to ~21 M_{Jup} and ~3-4 M_{Jup}, respectively, with the mass of B being well below the observed tip of the planetary mass function and the theoretical deuterium-burning limit. After removing probable Lower Centaurus-Crux (LCC) members from the TWA sample, as well as the probable non-member TWA 22, the remaining TWA membership is found to have distances of 49 ± 3 (s.e.m.) $\pm$ 12 (1σ) pc, and an internal 1D velocity dispersion of $0.8^{+0.3}_{-0.2}$ km s^{-1}. There is weak evidence that the TWA is expanding, and the data are consistent with a lower limit on the expansion age of 10 Myr (95% confidence).

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http://xxx.lanl.gov/abs/astro-ph/0507416 or http://cfa-www.harvard.edu/~emamajek/index.html

Disc orientations in pre-main-sequence multiple systems. A study in southern star formation regions

Jean-Louis Monin[1,2], **Francois Menard**[1] **and Nicolas Peretto**[3]

[1] Laboratoire Astrophysique Grenoble UJF BP53 38041 Grenoble France
[3] CEA/DSM/DAPNIA, Service d'Astrophysique, CEA Saclay, 91191 Gif-sur-Yvette Cedex, France
[2] Institut Universitaire de France

E-mail contact: Jean-Louis.Monin@obs.ujf-grenoble.fr

Classical T Tauri stars are encircled by accretion discs most of the time unresolved by conventional imaging observation. However, numerical simulations show that unresolved aperture linear polarimetry can be used to extract information about the geometry of the immediate circumstellar medium that scatter the starlight. Monin, Ménard & Duchêne (1998) previously suggested that polarimetry can be used to trace the relative orientation of discs in young binary systems in order to shed light on the stellar and planet formation process. In this paper, we report on new VLT/FORS1 optical linear polarisation measurements of 23 southern binaries spanning a range of separation from 0.8″ to 10″. In each field, the polarisation of the central binary is extracted, as well as the polarisation of nearby stars in order to estimate the local interstellar polarisation. We find that, in general, the linear polarisation vectors of individual components in binary systems tend to be parallel to each other. The amplitude of their polarisations are also correlated. These findings are in agreement with our previous work and extend the trend to smaller separations. They are also similar to other studies, e.g., Donar et al. 1999; Jensen et al. 2000, 2004; Wolf et al. 2001. However, we also find a few systems showing large differences in polarisation level, possibly indicating different inclinations to the line-of-sight for their discs.

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GQ Lup and its common proper motion companion

Markus Mugrauer[1] **and Ralph Neuhäuser**[1]

[1] Astrophysikalisches Institut, Universität Jena, Schillergässchen 2, D-07745 Jena, Germany

E-mail contact: markus and rne@astro.uni-jena.de

Recently, Neuhäuser et al. (2005) presented evidence for a sub-stellar, common proper motion companion to GQ Lup. With two theoretical mass estimates, both below the Deuterium burning minimum mass limit, the companion is probably a planet imaged directly. We present here a more detailed astrometric analysis of the GQ Lup system, using all the (different) proper motions published for the primary. The common proper motion is significant in all cases, also when taking into account the error in parallax or distance (140 ± 50 pc). When using the weighted mean, the significance for common proper motion of GQ Lup and its companion is 7 + 4 sigma for no change in separation plus 8 sigma for no change in position angle. We also discuss the question, whether GQ Lup and its common-proper motion companion are not bound, but share the same or similar proper motion as two independent members of the Lupus T association, which is a moving group, where most members should have the same motion anyway. Given our discussion, this hypothesis can be rejected by several sigma: The probability to find by chance an L-dwarf fainter than K = 14 mag within 0.7325 arcsec with (almost) the same proper motion of GQ Lup is only $\leq 3 \cdot 10^{-10}$. The orbital motion of the system is not yet detected (1.4 ± 2.2 mas/yr), but is probably smaller than the escape velocity (5.3 ± 2.1 mas/yr), so that the system may well be gravitationally bound and stable. This is different for the 2MASSWJ1207334-393254 system, as we also show.

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An 850 μm survey for dust around solar mass stars

Joan Najita[1] **and Jonathan Williams**[2]

[1] National Optical Astronomy Observatory, Tucson, AZ, USA
[2] Institute for Astronomy, University of Hawaii, Honolulu, HI, USA

E-mail contact: najita@noao.edu

We present the results of an 850 μm JCMT/SCUBA survey for dust around 13 nearby solar mass stars. The dust mass sensitivity ranged from 5×10^{-3} to 0.16 $M_\oplus$. Three sources were detected in the survey, one of which (HD 107146) has been previously reported. One of the other two submillimeter sources, HD 104860, was not detected by IRAS and is surrounded by a cold, massive dust disk with a dust temperature and mass of T_{dust} = 33 K and M_{dust} = 0.16 $M_\oplus$. The third source, HD 8907, was detected by IRAS and ISO at 60 − 87 μm, and has a dust temperature and mass of T_{dust} = 48 K and M_{dust} = 0.036 $M_\oplus$. We find that the deduced masses and radii of the dust disks in our sample are roughly consistent with models for the collisional evolution of planetesimal disks with embedded planets. We also searched for residual gas in two of the three systems with detected submillimeter excesses and place limits on the mass of gas residing in these systems.

When the properties measured for the detected excess sources are combined with the larger population of submillimeter excess sources from the literature, we find strong evidence that the mass in small grains declines significantly on a $\sim$ 200 Myr timescale, approximately inversely with age. However, we also find that the characteristic dust radii of the population, obtained from the dust temperature of the excess and assuming blackbody grains, is uncorrelated with age. This is in contrast to self-stirred collisional models for debris disk evolution which predict a trend of radius increasing with age $t_{age} \propto R_d^3$. The lack of agreement suggests that processes beyond self-stirring, such as giant planet formation, play a role in the evolutionary histories of planetesimal disks.

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Probing the formation of intermediate- to high-mass stars in protoclusters: A detailed millimeter study of the NGC 2264 clumps

N. Peretto[1], **Ph. André**[1,2] **and A. Belloche**[3]

[1]Service d'Astrophysique, CEA/DSM/DAPNIA, C.E. Saclay, Orme des Merisiers, 91191 Gif-sur-Yvette, France
[2]AIM – Unit Mixte de Recherche CEA – CNRS – Universit Paris VII – UMR n 7158
[3]Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

peretto@cea.fr, pandre@cea.fr

We present the results of dust continuum and molecular line observations of two massive cluster-forming clumps, NGC 2264-C and NGC 2264-D, including extensive mapping performed with the MAMBO bolometer array and the HERA heterodyne array on the IRAM 30m telescope. Both NGC 2264 clumps are located in the Mon OB1 giant molecular cloud complex, adjacent to one another. Twelve and fifteen compact millimeter continuum sources (i.e. MMSs) are identified in clumps C and D, respectively. These MMSs have larger sizes and masses than the millimeter continuum condensations detected in well-known nearby protoclusters such as ρ Ophiuchi. The MMSs of NGC 2264 are more similar in size to the DCO^+ 'cores' of ρ Oph, although they are somewhat denser and exhibit broader linewidths. Most of the MMSs of NGC 2264-C harbor candidate Class 0 protostars associated with shocked molecular hydrogen jets. Evidence for widespread infall motions is found in, e.g., HCO^+(3–2) or CS(3–2) in both NGC 2264-C and NGC 2264-D. A sharp velocity discontinuity $\sim$ 2 km.s^{-1} in amplitude is observed in N_2H^+(1–0) and $H^{13}CO^+$(1–0) in the central, innermost part of NGC 2264-C, which we interpret as the signature of a strong dynamical interaction between two MMSs and their possible merging with the central MMS C-MM3. Radiative transfer modelling supports the idea that NGC 2264-C is a highly unstable prolate clump in the process of collapsing along its long axis on a near free-fall dynamical timescale $\sim 1.7\times10^5$ yr. Our model fit of this large-scale collapse suggests a maximum mass inflow rate $\sim 3\times10^{-3}$ M$_\odot$ yr^{-1} toward the central protostellar object C-MM3. In NGC 2264-D, we estimate a mass infall rate $\dot{M}_{DMM1} \sim 1.1\times10^{-4}$ M$_\odot$ yr^{-1} toward the rotating Class 0 object D-MM1, also based on radiative transfer modelling of the observations. Such infall rates are sufficiently high to overcome radiation pressure and allow the formation of $\sim$ 20 M$_\odot$ stars by accretion in $\sim 1.7\times10^5$ yr, i.e., a time similar to the global dynamical timescale of the central part of NGC 2264-C. We conclude that we are likely witnessing the formation of a high-mass ($\geq$ 10 M$_\odot$) protostar in the central part of NGC 2264-C. Our results suggest a picture of massive star formation intermediate between the scenario of stellar mergers of Bonnell et al. (1998) and the massive turbulent core model of McKee & Tan (2003), whereby a turbulent, massive ultra-dense core is formed by the gravitational merger of two or more Class 0 protostellar cores at the center of a collapsing protocluster.

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Disk Evolution in Cep OB2: Results from the Spitzer Space Telescope

Aurora Sicilia-Aguilar[1], Lee W. Hartmann[1], Nuria Calvet[1], S.T. Megeath[1], James Muzerolle[2], Lori Allen[1], Paola D'Alessio[3], Bruno Merin[4], John Stauffer[5], Erick Young[2] and Charles Lada[1]

[1] Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[2] Steward Observatory, 933 N. Cherry Avenue, The University of Arizona, Tucson, AZ 85721, USA
[3] Centro de Radioastronomía y Astrofísica, Apartado Postal 72-3 (Xangari), 58089 Morelia, Michoacán, Mexico
[4] Sterrewacht Leiden, Niels Bohrweg, 2, PO Box 9513, NL-2300 RA, Leiden, The Netherlands
[5] Spitzer Science Center, California Institute of Technology, MS 314-6, Pasadena, CA 91125, USA

E-mail contact: asicilia@cfa.harvard.edu

We present the results of an infrared imaging survey of two clusters in the Cep OB2 Association, Tr 37 and NGC 7160, using the IRAC and MIPS instruments on board the *Spitzer Space Telescope*. Our observations cover the wavelength range from 3.6 to 24 μm, allowing us to detect disk emission over a typical range of radii ~0.1 to ~20 AU from the central star. In Tr 37, with an age of about 4 Myr, about 48% of the low-mass stars exhibit detectable disk emission in the IRAC bands. Roughly 10% of the stars with disks may be "transition" objects, with essentially photospheric fluxes at wavelengths $\leq$ 4.5μm but with excesses at longer wavelengths, indicating an optically thin inner disk. The median optically-thick disk emission in Tr 37 is lower than the corresponding median for stars in the younger Taurus region; the decrease in infrared excess is larger at 6 – 8μm than at 24μm, suggesting that grain growth and/or dust settling has proceeded faster at smaller disk radii, as expected on general theoretical grounds. Only about 4% of the low-mass stars in the 10 Myr-old cluster NGC 7160 show detectable infrared disk emission. We also find evidence for 24μm excesses around a few intermediate-mass stars, which may represent so-called "debris disk" systems. Our observations provide new constraints on disk evolution through an important age range.

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http://cfa-www.harvard.edu/cfa/youngstars/publications.html

H_2O maser emission from bright rimmed clouds in the northern hemisphere

R. Valdettaro[1], F. Palla[1], J. Brand[2] and R. Cesaroni[1]

[1] INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi, 5, I-50125 Firenze, Italy
[2] INAF-Istituto di Radioastronomia, Via Gobetti 101, I-40129 Bologna, Italy

E-mail contact: rv@arcetri.astro.it

We report the results of a multi-epoch survey of water maser observations at 22.2 GHz with the Medicina radiotelescope from 44 bright rimmed clouds (BRCs) of the northern hemisphere identified by Sugitani et al. (1989) as potential sites of star formation. The data span 16 years of observations and allow to draw conclusions about the maser detection rate in this class of objects. In spite of the relatively high far-infrared luminosities of the embedded sources ($L_{\rm FIR} \geq 10^2$ $L_\odot$), H_2O maser emission was detected towards three globules only. Since the occurrence of water masers is higher towards bright IRAS sources, the lack of frequent H_2O maser emission is somewhat surprising if the suggestion of induced intermediate- and high-mass star formation within these globules is correct. The maser properties of two BRCs are characteristic of exciting sources of low-mass, while the last one (BRC 38) is consistent with an intermediate-mass object. We argue that most BRCs host young stellar objects of low-luminosity, likely in an evolutionary phase later than the protostellar Class 0 sources, and that a significant contribution to the observd IRAS luminosity comes from warm dust heated by the radiation from the bright rim.

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On the origin of the X-ray emission towards the early Herbig Be star MWC 297

Jorick S. Vink[1] , Paul M. O'Neill[1], Sebastian G. Els[2], and Janet E. Drew[1]

[1] Imperial College London, UK
[2] Caltech, CA, USA

E-mail contact: j.vink@imperial.ac.uk

We present high resolution AO-corrected coronographic near-infrared imaging on the early-type Herbig Be star MWC 297. X-ray flaring has been reported towards this young object, however this has been difficult to reconcile with its early spectral type (B1.5) and relatively high mass (10 Msun). Our infrared and X-ray analysis shows that the X-ray flaring is likely due to a late-type star in the same field. The case of MWC 297 emphasizes the need for coronographic imaging to address the reality of X-ray emission towards Herbig Ae/Be stars, which is needed to understand the differences between low and high-mass star formation.

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Near infrared and the inner regions of protoplanetary disks

Dejan Vinkovic[1], Zeljko Ivezic[2], Tomislav Jurkic[3] and Moshe Elitzur[4]

[1] Institute for Advanced Study, School of Natural Sciences, Einstein Drive, Princeton, NJ 08540, USA
[2] Department of Astronomy, University of Washington, Seattle, WA 98195, USA
[3] Department of Physics, Faculty of Science, University of Zagreb, Bijenivka 32, HR-10002 Zagreb, Croatia
[4] Department of Physics and Astronomy, University of Kentucky, Lexington, KY 40506, USA

E-mail contact: dejan@ias.edu

We examine the "puffed-up inner disk" model (Dullemond, Dominik & Natta 2001), proposed for explaining the near-IR excess radiation from Herbig Ae/Be stars. Detailed model computations show that the observed near-IR excess requires more hot dust than is contained in the puffed-up disk rim. The rim can produce the observed near-IR excess only if its dust has perfectly gray opacity, but such dust is in conflict with the observed 10μm spectral feature. We find that a compact ($\sim$ 10 AU) tenuous ($\tau_V <\sim$ 0.4) dusty halo around the disk inner regions contains enough dust to readily explain the observations. Furthermore, this model also resolves the puzzling relationship noted by Monnier and Millan-Gabet (2002) between luminosity and the interferometric inner radii of disks.

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Dust extinction and absorption: the challenge of porous grains

N. V. Voshchinnikov[1,2]**, V.B. Il'in**[1,2]**, Th. Henning**[3] **and D.N. Dubkova**[1]

[1]Sobolev Astronomical Institute, St. Petersburg University, Universitetskii prosp. 28, St. Petersburg, 198504 Russia
[2]Isaac Newton Institute of Chile, St. Petersburg Branch
[3]Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: nvv@astro.spbu.ru

In many models of dusty objects in space the grains are assumed to be composite or fluffy. However, the computation of the optical properties of such particles is still a very difficult problem. We analyze how the increase of grain porosity influences basic features of cosmic dust — interstellar extinction, dust temperature, infrared bands and millimeter opacity.

It is found that an increase of porosity leads to an increase of extinction cross sections at some wavelengths and a decrease at others depending on the grain model. However, this behaviour is sufficient to reproduce the extinction curve in the direction of the star σ Sco using current solar abundances. In the case of the star ζ Oph our model requires larger amounts of carbon and iron in the dust-phase than is available. Porous grains can reproduce the flat extinction across the $3 - 8\,\mu$m wavelength range measured for several lines of sight by *ISO* and *Spitzer*.

Porous grains are generally cooler than compact grains. At the same time, the temperature of very porous grains becomes slightly larger in the case of the EMT-Mie calculations in comparison with the results found from the layered-sphere model. The layered-sphere model predicts a broadening of infrared bands and a shift of the peak position to larger wavelengths as porosity grows. In the case of the EMT-Mie model variations of the feature profile are less significant. It is also shown that the millimeter mass absorption coefficients grow as porosity increases with a faster growth occurring for particles with Rayleigh/non-Rayleigh inclusions. As a result, for very porous particles the coefficients given by two models can differ by a factor of about 3.

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Estimation and reduction of the uncertainties in chemical models: Application to hot core chemistry

V. Wakelam[1]**, F. Selsis**[2]**, E. Herbst**[1, 3] **and P. Caselli**[4]

[1] Department of Physics, The Ohio State University, Columbus, OH 43210, USA
[2] Centre de Recherche Astronomique de Lyon, Ecole Normale Supérieure, 46 Allée d'Italie, F-69364 Lyon cedex 7, France
[3] Departments of Astronomy and Chemistry, The Ohio State University, Columbus, OH 43210, USA
[4] INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi, 50125 Firenze, Italy

E-mail contact: wakelam@mps.ohio-state.edu

It is not common to consider the role of uncertainties in the rate coefficients used in interstellar gas-phase chemical models. In this paper, we report a new method to determine both the uncertainties in calculated molecular abundances and their sensitivities to underlying uncertainties in the kinetic data utilized. The method is used in hot core models to determine if previous analyses of the age and the applicable cosmic-ray ionization rate are valid. We conclude that for young hot cores ($\leq 10^4$ yr), the modeling uncertainties related to rate coefficients are reasonable so that comparisons with observations make sense. On the contrary, the modeling of older hot cores is characterized by strong uncertainties for some of the important species. In both cases, it is crucial to take into account these uncertainties to draw conclusions from the comparison of observations with chemical models.

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Preprints can be found at this address: http://www.physics.ohio-state.edu/~wakelam/3673.pdf

The intriguing giant bow shocks near HH 131

Min Wan[1]**, Junichi Noumaru**[2]**, Hongchi Wang**[1]**, Ji Yang**[1] **and Jiansheng Chen**[3]

[1] Purple Mountain Observatory, Academia Sinica, Nanjing 210008, China
[2] SUBARU project, Japan
[3] National Astronomical Observatories, Chinese Academy of Sciences, A20 Datun Road, Chaoyang District, Beijing 100012, China

E-mail contact: mwang@pmo.ac.cn

Using the High Dispersion Spectrograph (HDS) at the Subaru Telescope, echelle spectra of two giant arcs, i.e. nebulosities

Cw and L (hereafter Nebu. Cw and L, or simply Cw and L) associated with HH 131 in Orion are presented. Typical emission lines of Herbig-Haro (HH) objects have been detected towards Nebu. Cw with the broadband filter KV 408. With the low dispersion spectrograph at the National Astronomical Observatories (NAO) 2.16 m telescope, spectra of Nebu. C, L and K are obtained, which also show strong [S II]$\lambda\lambda$ 6717/6731, Hα and [N II]6583 emission lines. Position-velocity distributions of Cw and L are analyzed from the long-slit spectra observed with the HDS Hα narrowband filter. The fastest radial velocity of Cw is V_r $\sim$–18.0 km s^{-1}. When the flow at L goes to the south, it slows down. The fastest radial velocity of L has been observed of –45.0 km s^{-1} and the slowest value is about –18.3 km s^{-1}, the radial velocity gradient is about 200 km s^{-1} pc^{-1}. The similarity of the fastest radial velocity of Cw to the slowest value of L and their positional connection indicate that they are physically associated. There is a tendency for the entire flow to become less excited and less ionized when going further to the south (i.e., from Nebu. K, L to C), where the most extended (and presumably evolved) objects are seen. The electron densities of all the observed nebulosities are low ($n_{\rm e}$ $\sim$10^2 cm^{-3}). Double kinematic signatures have been found in Cw from its [N II]6583 profiles while the observed Hα profiles of Cw are almost symmetric. Bow shock models appear to agree with the observed position-velocity diagrams of the [N II] spectra better than Hα spectra, and a bow shock with its wing, apex and postshock has been possibly revealed near Cw from the [N II] emission. With the suggestion that these arcs are HH shocks possibly ejected out of the Orion A molecular cloud by an uncertain source, their spectra show low to intermediate excitation from their diagnostic line ratios.

Accepted by The Astronomical Journal

http://jets.pmo.ac.cn/preprints.html or astro-ph/0508203, the latter contains images of low quality

Measuring the Magnetic Field on the Classical T Tauri Star TW Hydrae

Hao Yang[1]**, Christopher M. Johns–Krull**[1] **and Jeff A. Valenti**[2]

[1] Physics & Astronomy Dept., Rice University, 6100 Main St., MS-108, Houston, TX 77005, USA
[2] Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21210, USA

E-mail contact: haoyang@rice.edu

We present infrared (IR) and optical echelle spectra of the Classical T Tauri star TW Hydrae. Using the optical data, we perform detailed spectrum synthesis to fit atomic and molecular absorption lines and determine key stellar parameters: $T_{\rm eff}$ = 4126 ± 24 K, $\log g = 4.84 \pm 0.16$, [M/H]= -0.10 ± 0.12, $v \sin i = 5.8 \pm 0.6$ km s^{-1}. The IR spectrum is used to look for Zeeman broadening of photospheric absorption lines. We fit four Zeeman sensitive Ti I lines near 2.2 microns and find the average value of the magnetic field over the entire surface is $\overline{B}$ = 2.61 ± 0.23 kG. In addition, several nearby magnetically insensitive CO lines show no excess broadening above that produced by stellar rotation and instrumental broadening, reinforcing the magnetic interpretation for the width of the Ti I lines. We carry out extensive tests to quantify systematic errors in our analysis technique which may result from inaccurate knowledge of the effective temperature or gravity, finding that reasonable errors in these quantities produce a $\sim$ 10% uncertainty in the mean field measurement.

Accepted by Astrophys. J.

Abstracts of papers in Nature and Science

Because of embargoes on preprints for Nature and Science, abstracts for these two journals will be accepted for papers that have already been published

CO self-shielding and oxygen isotope anomalies in the solar nebula

J.R. Lyons, and E.D. Young

[1] Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA, 90095, USA

E-mail contact: jrl@ess.ucla.edu

The abundances of oxygen isotopes in the most refractory mineral phases (calcium aluminium inclusions or CAIs) in meteorites1 have hitherto defied explanation. Most processes fractionate isotopes by nuclear mass; that is, ^{18}O is twice as fractionated as ^{17}O, relative to ^{16}O. In CAIs ^{17}O and ^{18}O are nearly equally fractionated, implying a fundamentally different fractionation mechanism. The CAI data were originally interpreted as evidence for supernova input of pure ^{16}O into the solar nebula, but the lack of a similar isotope trend in other elements argues against this explanation. A symmetry-dependent fractionation mechanism may have occurred in the inner solar nebula, but experimental evidence is lacking. Isotope-selective photodissociation of CO in the innermost solar nebula might explain the CAI data, but the high temperatures in this region would have rapidly erased the signature. Here we report time-dependent calculations of CO photodissociation in the cooler surface region of a turbulent nebula. If the surface was irradiated by a far-ultraviolet flux $\sim 10^3$ times that of the local interstellar medium (for example, owing to an O or B star within 1 parsec of the protosun), then substantial fractionation of the oxygen isotopes was possible on a timescale of $\sim 10^5$ years. We predict that similarly irradiated protoplanetary disks will have H_2O enriched in ^{17}O and ^{18}O by several tens of percent relative to CO.

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A Disk of Dust and Molecular Gas around a High-Mass Protostar

Nimesh A. Patel[1], Salvador Curiel[1,2], T. K. Sridharan[1], Qizhou Zhang[1], Todd R. Hunter[1], Paul T. P. Ho[1], José M. Torrelles[3], James M. Moran[1], José F. Gomez[4,5] and Guillem Anglada[4]

[1] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA
[2] Instituto de Astronomia, UNAM, Unidad Morelia, Mexico
[3] Consejo Superior de Investigaciones Científicas-IEEC,
[4] Instituto de Astrofisica de Andalucia, CSIC, Granada, Spain
[5] Laboratorio de Astrofisica Espacial y Fisica Fundamental, INTA, Spain

E-mail contact: npatel@cfa.harvard.edu

The processes leading to the birth of low-mass stars such as our Sun have been well studied, but the formation of high-mass ($> 8\times$ Sun's mass $M_\odot$) stars has heretofore remained poorly understood. Recent observational studies suggest that high-mass stars may form in essentially the same way as low-mass stars, namely via an accretion process, instead of via merging of several low-mass ($< 8M_\odot$) stars. However, there is as yet no conclusive evidence. Here, we report the discovery of a flattened disk-like structure observed at submillimeter wavelengths, centered on a massive 15 $M_\odot$ protostar in the Cepheus-A region. The disk, with a radius of about 330 astronomical units (AU) and a mass of 1 to 8 $M_\odot$, is detected in dust continuum as well as in molecular line emission. Its perpendicular orientation to, and spatial coincidence with the central embedded powerful bipolar radio jet, provides the best evidence yet that massive stars form via disk accretion in direct analogy to the formation of low-mass stars.

Published by Nature (1 September 2005 issue; volume 437, p109)

http://www.nature.com/nature/journal/v437/n7055/pdf/nature04011.pdf

High angular resolution studies of the structure and evolution of protoplanetary disks

Joshua A. Eisner

Thesis work conducted at: California Institute of Technology, USA

Current address: Department of Astronomy, 601 Campbell Hall, University of California at Berkeley, Berkeley, CA 94720, USA

Electronic mail: jae@astron.berkeley.edu

Ph.D dissertation directed by: Lynne Hillenbrand and Anneila Sargent

Ph.D degree awarded: June 2005

Young stars are surrounded by massive, rotating disks of dust and gas, which supply a reservoir of material that may be incorporated into planets or accreted onto the central star. In this dissertation, I use high angular resolution observations at a range of wavelengths to understand the structure, ubiquity, and evolutionary timescales of protoplanetary disks.

First, I describe a study of Class I protostars, objects believed to be at an evolutionary stage between collapsing spherical clouds and fully-assembled young stars surrounded by protoplanetary disks. I use a Monte Carlo radiative transfer code to model new 0.9 μm scattered light images, 1.3 mm continuum images, and broadband spectral energy distributions. This modeling shows that Class I sources are probably surrounded by massive protoplanetary disks embedded in massive infalling envelopes. For the best-fitting models of the circumstellar dust distributions, I determine several important properties, including envelope and disk masses, mass infall rates, and system inclinations, and I use these results to constrain the evolutionary stage of these objects.

Second, I discuss observations of the innermost regions of more evolved disks around T Tauri and Herbig Ae/Be stars, obtained with the Palomar Testbed and Keck Interferometers. I constrain the spatial and temperature structure of the circumstellar material at sub-AU radii, and demonstrate that lower-mass stars are surrounded by inclined disks with puffed-up inner edges 0.1-1 AU from the star. In contrast, the truncated inner disks around more massive stars may not puff-up, indicating that disk structure depends on stellar properties. I discuss the implications of these results for disk accretion, terrestrial planet formation and giant planet migration.

Finally, I put these detailed studies of disk structure into a broader context by constraining the mass distribution and evolutionary timescales of circumstellar disks. Using the Owens Valley Millimeter Array, I mapped the millimeter continuum emission toward $>$ 300 low-mass stars in the NGC 2024 and Orion Nebula clusters. These observations demonstrate that the average disk mass in each cluster is comparable to the “minimum-mass protosolar nebula”, and that there may be disk evolution on one million year timescales.

Computational and Theoretical Investigations of Star Formation

Mark Krumholz

University of California, Berkeley, USA

Astronomy Department, 601 Campbell Hall, UC Berkeley, Berkeley, CA 94720-7304

Address as of 1 September 2005: Astrophysics Department, Princeton University, Peyton Hall, Ivy Lane, Princeton, NJ 08544-1001, USA

Electronic mail: krumholz@astron.berkeley.edu

Ph.D dissertation directed by: Christopher McKee and Richard Klein

Ph.D degree awarded: August 2005

I investigate three related questions in the theory of star formation. First, I consider the physical mechanism of massive star formation. Massive stars reach the main sequence while still accreting from their natal clouds, leading to a huge radiation pressure force on dust grains suspended in the incoming gas. Early calculations found that this limits stellar masses to $\lesssim 20 - 40$ $M_\odot$, far smaller than the most massive stars observed. I demonstrate two new mechanisms by which accretion can continue despite radiation pressure. First, radiation holding up a massive infalling envelope is subject to Rayleigh-Taylor instability, which forces the accreting gas into optically thick filaments that are shielded from radiation and channel gas to the star. Second, massive protostars have powerful outflows that punch optically thin cavities through the envelope. These channel radiation away from the accreting gas, greatly reducing the radiation pressure force it experiences.

Second, I argue that the stellar initial mass function (IMF) does not originate from the "competitive accretion" of unbound gas by seed protostars. I provide an approximate solution to the problem of Bondi-Hoyle accretion in a turbulent medium, and use this solution to show that the rate of competitive accretion in environments like observed star-forming regions is too low to substantially affect the masses of newborn stars. Only if star-forming clumps undergo a global collapse to a state far denser than any thus far observed is competitive accretion a viable mechanism for producing the IMF.

Third, I give a theoretical prediction for the star formation rate in a medium where star formation is regulated by supersonic turbulence. Starting from the approximation that stars form in any region that is sufficiently overdense for the local potential energy to exceed the turbulent kinetic energy, I derive a formula for the star formation rate in terms of the virial parameter and Mach number of a star-forming cloud. I show that this prediction is consistent with simulations, that it correctly predicts the observed star formation rate in the Milky Way, and that it reproduces the observed Kennicutt-Schmidt Law for star formation in galaxies.

http://astron.berkeley.edu/~krumholz/docs/dissertation.pdf

Chemical and Dynamical Conditions in Low-Mass Star Forming Cores

Jeong-Eun Lee

Dept. of Astronomy, University of Texas at Austin, USA

Address as of 16 Aug 2005: Physics and Astronomy Building, 430 Portola Plaza, Box 951547, Los Angeles, CA 90095-1547, USA

Electronic mail: jelee@astro.ucla.edu

Ph.D dissertation directed by: Neal J. Evans II

Ph.D degree awarded: August 2005

In order to understand the chemical and dynamical conditions in low mass star forming cores, this dissertation focuses on 1) the development of an evolutionary chemical model combining a dynamical model of star formation and an evolutionary model of luminosity in the process of star formation, and 2) comparisons of observations with results of the chemical model or with simple empirical models. The evolutionary chemical model combines self-consistently a dynamical model (Shu's inside-out collapse model) with a chemical network, which includes interactions between gas and dust grains as well as gas-phase chemistry. Dust radiative transfer and gas-energetics codes are also combined with the evolutionary model to provide proper dust and gas temperatures. The evolutionary model shows that carbon- and sulfur-bearing molecules such as CO and CS are frozen onto grain surfaces in pre-protostellar cores, so nitrogen-bearing molecules such as N_2H^+ and NH_3 are good tracers of cold and dense material before stars form. However, once a central star forms, and in turn, surrounding material is heated by the formation of the protostellar object, molecules start to evaporate from grain surfaces, making other molecules than N_2H^+ and NH_3 better tracers. The evolutionary model developed in this thesis has been compared with other, simpler models, such as empirical models and static models, to show the effects of the dynamical evolution on the chemical evolution. Observations toward three pre-protostellar cores (L1512, L1544, and L1689B) and a more evolved core (L1251B) support the results of the evolutionary chemical model.

Structure and Dynamics at the Central 10 Parsecs of the Galaxy

Sungho Lee

School of Earth and Environmental Sciences, Seoul National University, South Korea

Korea Astronomy and Space Science Institute, Daejeon 305-348, South Korea

Electronic mail: leesh@kasi.re.kr

Ph.D dissertation directed by: Sang-Gak Lee

Ph.D degree awarded: August 2005

The Galactic center influences the current nature as well as the formation, the evolution and the future fate of the Milky Way. The Galactic nucleus stands for the galactic nuclei of other galaxies and provides an opportunity to study the environment around a super-massive black hole (SMBH) at high spatial resolution. The central 10 pc of the Galaxy, the Sgr A region, contains several principal components; the SMBH candidate (Sgr A*), the Central cluster, the circum-nuclear disk (CND), Sgr A West, a powerful supernova-like remnant (Sgr A East), and surrounding molecular clouds. Developing a consistent picture of the interactions between these components will improve our understanding of the Galaxy and the nature of galactic nuclei in general. Previous studies on the spatial and dynamical relationships between the various objects are mostly based on indirect and qualitative evidence and leave many unsolved questions, which need more robust evidence. Molecular hydrogen (H_2) emission has been used as an excellent tracer and diagnostic for interactions between dense molecular clouds and hot, powerful sources.

We observed the H_2 $1-0$ S(1) ($\lambda = 2.1218\mu$m) and H_2 $2-1$ S(1) ($\lambda = 2.2477\mu$m) emission line spectra from the interaction regions between Sgr A East, the CND, and the surrounding molecular clouds. Using the long-slit Cooled Grating Spectrometer 4 (CGS4) with an echelle grating at the 3.8 m United Kingdom Infrared Telescope (UKIRT) on Mauna Kea, we scanned 56 positions in the interaction regions. We reduced 2-D spectral images using IRAF and analyzed a 3-D data cube using MIRIAD. The data cube has the H_2 information both in space (with a resolution of $\sim$ 2 arcsec) and in velocity (with a resolution of $\sim$ 18 km s^{-1}). The H_2 $1-0$ S(1) data cube was directly compared with the NH_3(3,3) data cube from McGary, Coil, & Ho (2001, ApJ, 559, 326) to investigate the gas kinematics.

Based on the H_2 $1-0$ S(1) and $2-1$ S(1) line intensities and gas kinematics, we concluded that the H_2 excitation can be explained by two mechanisms; a combination of fluorescence and C-shocks in very strong magnetic fields, or a mixture of slow C-shocks and fast J-shocks. We estimated shock velocities ($\sim$ 100 km s^{-1}) of Sgr A East by comparing H_2 line profiles with those of NH_3. From the distribution of the shocked H_2 emission, we determined the interacting boundary of Sgr A East in projection as an ellipse with the center at $\sim$ 1.5 pc offset from Sgr A* and the dimension of 10.8 pc $\times$ 7.6 pc. We also determined the positional relationship between Sgr A East and the molecular clouds along the line-of-sight and suggested a revised model for the 3-D structure of the central 10 pc. From the estimated shock velocities, we deduced the initial explosion energy ($0.2–4 \times 10^{53}$ ergs) of Sgr A East. This extremely large energy excludes the hypothesis of a single, typical, supernova (SN) for the origin of Sgr A East. We examined other hypotheses (tidal disruption of a star by the SMBH, multiple supernovae, and a hypernova) and we concluded that a hypernova (collapsar or microquasar) is the most probable origin of Sgr A East.

Based on the energy, we investigated the influences of the Sgr A East-like explosions (hypernovae) and normal SNe on the mass inflow to the Galactic nucleus. We suggest a scenario that the continuous mass inflow into the Galactic nucleus makes it active by igniting the SMBH or stimulating a starburst every $\sim 10^8$ yr, but each active phase continues only $\lesssim 10^7$ yr since a large number of SNe resulting from newly born massive stars cease the mass supply soon. The Galactic nucleus is likely to spend only about 1/10 of its life in active. As for the recent history of the central 10 pc, the mass inflow restarted several 10^6 yr ago after a quiescent phase for $\sim 10^8$ yr. In its usual schedule, the Galactic nucleus would continue its activity for a few 10^6 yr more from now before a huge number of SNe occur. However, the active phase was unexpectedly ceased $\sim 10^4$ yr ago, by Sgr A East.

http://www.kasi.re.kr/ leesh/pub/thesis/leesh0726.pdf

Disk Evolution at the Ages of Planet Formation

Aurora Sicilia-Aguilar

Harvard-Smithsonian Center for Astrophysics, Cambridge, USA; Universidad Autonoma de Madrid, Madrid, Spain

Address as of 1 Sept 2005: Max-Planck-Institut fuer Astronomie, Koenigstuhl 17, D-69117 Heidelberg, Germany

Electronic mail: sicilia@mpia-hd.mpg.de

Ph.D dissertation directed by: Lee Hartmann

Ph.D degree awarded: June 2005

This thesis comprises the multiwavelength study of young stars and protoplanetary disks through the ages of 1-10 Myr, when disk dissipation and planet formation are supposed to occur, using some new generation of instruments, including the multi-fiber spectrographs Hectospec and Hectochelle, operating on the 6.5m Multiple Mirror Telescope (MMT) in Mount Hopkins, AZ. This is one of the first studies of stars aged 3-10 Myr, one of the first results obtained with Hectospec and Hectochelle, and one of the first Spitzer results on disk evolution.

First, I present the results of the optical and JHK observations of young stars in two young clusters in the Cep OB2 Association, Tr37 (embedded in the H II region IC 1396) and NGC 7160. Using low resolution optical spectra from the Hectospec multifiber spectrograph, a total of ∼165 and ∼50 low-mass members have been identified in Tr37 and in NGC 7160, respectively. Indicators of youth (Li absorption at 6707 Å) and accretion/chromospheric activity (Hα emission) are used to identify the low-mass cluster members. The accretion disk fraction is ∼40-45% for the low-mass stars in Tr 37, whereas only 1 star out of the NGC 7160 sample shows indications of active accretion. Optical photometry and theoretical isochrones are used to determine the age of the cluster members (4 Myr for Tr 37 and 10 Myr for NGC 7160). Accretion rates in Tr 37 ($\sim 10^{-8} M_{\odot} yr^{-1}$ in average) are derived from U band photometry. Only ∼50% of the accreting stars have JHK excesses (from 2MASS), which could be due to the geometry and orientation of their disks or be an indication dust settling/grain growth.

The presence of protoplanetary disks in Cep OB2 is determined using the data from a Guaranteed Time Observing (GTO) program to study disk evolution with Spitzer. The data, from the IRAC and MIPS instruments on Spitzer, cover the wavelength range from 3.6 to 24 μm, and allows to study the characteristics of disks at distances from ∼0.1-20 AU in accreting and non-accreting stars. The IR colors and spectral energy distributions (SEDs) of all members of the clusters are presented. The characteristics of disks and SEDs of the stars in NGC 7160 and Tr 37 are compared, as well as those obtained for younger regions (Taurus), finding significant evidence of disk evolution. The most striking differences between the 4 Myr old Tr 37 and younger regions (Taurus, the globule in Tr 37), appear as the color excesses for the shorter wavelengths (up to 5.8 μm) are significantly smaller. The comparison with models suggests that a noticeable amount of dust settling/grain growth and perhaps even disk clearing has occurred in the inner disk by the age of ∼4 Myr. Most of the IR emission from disks has disappeared by the age of ∼10 Myr, and the few remaining disks have suffered a more dramatic grain growth, settling and/or flattening affecting the emission at wavelengths from 3.6 to 24.0 μm. The data supports the picture that disk evolution starts in the inner part of the disks (fractions of AU) and proceeds to the outside with time. A small fraction of "transition objects", or non-accreting stars with disks evacuated in their innermost part (with excess emission only at wavelengths similar or longer than 5.8 μm), is also found in the cluster, suggesting a rapid evolution/dissipation of the disk once the inner part has been cleared or agglomerated into planets. The small fraction of these disks (a few percent of the total) suggests that the outer disk does not seem to survive for a long time once the inner disk has been dissipated or coagulated into planets.

The high- and intermediate-mass stars (BAF types) in the regions are also considered in the study, establishing their membership through spectral types and extinction. The IRAC and MIPS data from Spitzer reveal a total of 7 disks around BAF stars in Tr 37, of which 4 of them are optically thin, debris disks, plus 3 more debris disks in NGC 7160. These are among the youngest debris disks known, and one of the few examples of debris disks with well-determined ages (by using the low-mass, pre-Main Sequence stars).

Finally, well-known members of the younger Orion Nebula Cluster were observed with high-resolution optical spectra with Hectochelle /MMT in order to determine accretion disk fraction, and to set the best procedures for the detection of accretion in cases where the use of near-IR excesses and/or low-resolution spectra may present problems.

New Jobs

ASSISTANT PROFESSOR OF ASTRONOMY
(EXTRASOLAR PLANET STUDIES)
DEPARTMENT OF ASTRONOMY
UNIVERSITY OF FLORIDA
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The Department of Astronomy at the University of Florida has a tenure-track opening for an Assistant Professor on its faculty starting in August 2006. The successful candidate must be an astrophysicist involved in extrasolar planet studies (theory, observation or instrumentation). The position requires a commitment to undergraduate and graduate teaching, graduate student supervision, and the demonstrated ability to develop and conduct an independent program of research. Present research activities in the department include studies of solar system dynamics and dust, planet detection, planet and star formation and evolution, galactic evolution, active galactic nucleii and cosmology. We are also expanding and hiring in theoretical astrophysics. The department has a highly active program of infrared and optical instrumentation and technology development. Current activities include development of new generation multiple-object Doppler instruments for an all sky extrasolar planet survey with the Sloan telescope, infrared spectrometers and cameras for Gemini and the Gran Telescopio Canarias (GTC). The University is also a partner in the 10.4-meter GTC.

Interested applicants should submit a curriculum vitae, a statement of past accomplishments and future plans in research, and at least three letters of reference from people who are familiar with the applicant's ability. Applications should be sent to Professor Jian Ge, Search Committee Chair, University of Florida, Department of Astronomy, Box 112055, Gainesville, FL 32611-2055, before December 1, 2005. Anyone requiring special accommodations to complete this application should contact the Search Committee Chair. The University of Florida is an equal-opportunity affirmative action employer.

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

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

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

INAF - Osservatorio Astronomico di Palermo
Giuseppe S. Vaiana

Marie Curie Fellowships
Closing date: 30 November 2005

INAF - Osservatorio Astronomico di Palermo (OAPA) Giuseppe S. Vaiana will appoint one fellow in the area of Astrophysics under the European Commission's Marie Curie Actions Host Fellowship - Transfer of Knowledge programme "The Influence of Stellar High Energy Radiation on Planetary Atmospheres". The selected fellow will work on the interaction of stellar X-ray emission with circumstellar disks and/or planetary atmospheres.

The fellowship is expected to start before the end of May 2006 and to last 24 months.

Candidates should have a PhD or at least four years of full-time research experience at postgraduate level in a relevant field. In either case the candidate cannot have more than ten years of research experience.

The applicant must be national of a Member State of the European Community (other than Italy) or an Associated State, or otherwise residing in the Community or in an Associated State for at least four years out of the last five (except Italy). Candidates should not have been resident in Italy for more than 12 months in the three years prior to selection. Candidates from third countries could be considered, subject to formal approval by the European Commission. In the case of a researcher holding more than one nationality including the Italian one, (s)he could apply if (s)he has not resided in Italy during the previous 5 years. As an exception to the general rule, an Italian citizen can apply if (s)he can provide evidence testifying that (s)he has legally resided and had his/her main activity in a third country for at least four out of the last five years immediately prior to his/her appointment.

Gross salary is fixed at 3889.25 Euro per month, for the duration of the contraxt, plus a mobility allowance according to the family situation.

Female candidates are explicitly encouraged to apply. Applications should include

Documents certifying the doctoral degree or four years of full time research experience.
Statement of compliance with the eligibility requirements relative to the citizenship or residence.
Curriculum Vitae.
Publication list.
Description of applicant's research interests/program.
Copy of a valid picture identification (passport or national id card)
Two letters of recommendation. Documents 1,2,3,4,5 and 6 should be signed by the candidate. All documents should arrive by 30 November 2005 at:

INAF - Osservatorio Astronomico di Palermo
Marie Curie Fellowship Selection
Piazza del Parlamento 1
I-90134 Palermo, Italy

For further information contact:
Giusi Micela - giusi@astropa.unipa.it or see http://www.astropa.unipa.it/ISHERPA

Star Formation Postdoc at CfA

Applications are invited for the position of postdoctoral fellow at the Smithsonian Astrophysical Observatory (SAO) of the Harvard-Smithsonian Center for Astrophysics for a recent recipient of the Ph.D. degree to work with Dr. Charles J. Lada on observational studies of star formation and molecular cloud structure. The successful applicant is expected to take a leading role in a major program of star formation research which includes infrared spectroscopic and imaging studies of embedded clusters and protostellar objects as well as molecular spectral-line and infrared imaging studies of dense cloud cores. Facilities available for star formation research at CfA include the SMA, MMT and Magellan telesocpes. The successful applicant will work with astronomers at the CfA, ESO and the University of Florida to conduct the necessary observations and perform the reduction and analysis of the data.

Applicants should have experience with ground-based and/or space-based infrared observations and data analysis. Knowledge and experience with millimeter or submillimeter wavelength observations is also desirable. Familiarity with UNIX/LINUX as well as IDL and/or IRAF is required. The candidate should have a record of publications or achievements which have advanced the knowledge of star formation, molecular cloud physics or related fields. The position is for two years with extension to a third year possible, contingent on successful performance and availability of funds. The stipend is $50,000 with health insurance and can start as early as spring 2006 but no later than fall 2006. Interested candidates should submit a curriculum vita, a bibliography and a statement of research interest and should arrange for three letters of recommendation to be sent by the deadline. All materials should be sent to: Dr. Charles J. Lada Smithsonian Astrophysical Observatory, 60 Garden Street, MS 72, Cambridge MA, 02138, USA before 1 December 2005. Review of applications will begin in December and continue until the position is filled. The Smithsonian Observatory is an AAE/EEO employer.

E-mail Inquiries: clada@cfa.harvard.edu

Moving ... ??

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Postdoctoral Fellowship in High Mass Star Formation at High Angular Resolution - SMITHSONIAN ASTROPHYSICAL OBSERVATORY

Applications are invited for a postdoctoral fellowship in high-mass star formation at the Smithsonian Astrophysical Observatory of the Harvard Smithsonian Center for Astrophysics. The fellow will work with VLBI groups in the study of 3D gas motions close to high-mass young stellar objects, in order to characterize accretion/outflow processes and the role of magnetic fields. One long range goal will be creation of visualization tools and a movie, using spectral-line time-series images, of a YSO in Orion. Other star formation projects are possible, depending on appointee interest and experience. Use of the VLBA, VLA, MERLIN, and Smithsonian facilities such as the Submillimeter Array (SMA) and optical/infrared telescopes will be viewed with particular interest.

Candidates must possess a PhD in astrophysics or a related field. They must have demonstrated experience in radio interferometry and associated analysis software. Experience in the reduction of VLBI data is especially desirable. Familiarity with UNIX/LINUX, FORTRAN/C, and scripting is necessary. The position will be offered for one year, renewable for up to three, contingent on performance and funding. The stipend is $50,000 plus health insurance, and the start date is June 1, 2006. Later starts may be arranged. Further information can be obtained via email from Drs. Lincoln Greenhill and Liz Humphreys. Candidates should submit via email a CV, bibliography, preferred start date, and statement of research accomplishments and interests on or before December 1, 2005. Three letters of recommendation should also be received by Dr. Humphreys before this date as well. AAE/EOE

Postdoctoral Fellowship in High Mass Star Formation at High Angular Resolution
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
60 Garden St.
MS 42
Cambridge, MA 02138
USA
Tel: 617 496 7547
FAX: 617 495 7345

Email Submission Address: ehumphreys@cfa.harvard.edu

Email Inquiries: ehumphreys@cfa.harvard.edu, lgreenhill@cfa.harvard.edu

First Announcement

IOA Conference 2006: The Planet-Disc Connection

A conference ‘ The Planet-Disc Connection’ will be hosted by the Institute of Astronomy, Cambridge, from July 17-21 2006. Registration for this meeting will open early in 2006. Further information will be made available at the conference website http://www.ast.cam.ac.uk/meetings/discs06. Please address enquiries to discs06@ast.cam.ac.uk

Observations of the later evolutionary stages of discs around young stars offer the best opportunity to study planet formation from an observational perspective. Localised clearing of dust and gas in discs can be inferred from a variety of imaging/spectroscopic diagnostics and is often interpreted as evidence for planet formation; alternatively, such clearing results from some other process which needs to be taken into account when assessing the environment in which planets form.

A number of recent observational and theoretical developments make it particularly timely to hold a meeting on this subject in 2006. For example, mid IR photometry from Spitzer is proving crucial in defining the population of discs showing evidence for clearing from the inside-out, while coronagraphic imaging from HST is revealing complex structure in debris discs which may point to the presence of planets. At the same time, a wealth of multi-wavelength spectroscopic and photometric data can be assembled to address important issues such as the timescales for disc clearing, the spatial sequence of clearing and the whether dust and gas are dispersed together.

We will bring together observers to review what can be inferred from the recent data and theorists to report on advances in modeling disc clearing by planet formation and other mechanisms. We will also look forward to future facilities (such as ALMA and planned interferometric arrays in the optical) in order to assess the prospects for detecting unambiguous signatures of ongoing planet formation during the next decade.

S.O.C.

Cathie Clarke (IOA)

Ewine van Dishoeck (Leiden)

Jane Greaves (St Andrews)

Lee Hartmann (CfA)

David Hollenbach (NASA Ames)

Doug Lin (UCSC)

Michael Meyer (Arizona)

Jim Pringle (IOA)

Sebastian Wolf (Heidelberg)