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Abstracts of recently accepted papers

The low-mass Initial Mass Function in the 30 Doradus starburst cluster

M. Andersen[1], H. Zinnecker[2], A. Moneti[3], M. J. McCaughrean[4], B. Brandl[5], W. Brandner[6], G. Meylan[7] and D. Hunter[8]

[1] Space Science Department, European Space Agency, Keplerlaan 1, 2200 AG Noordwijk, Netherlands
[2] Astrophysical Institute Potsdam, An der Sternwarte 16, 14482 Potsdam Germany
[3] Institut d'Astrophysique, Paris 98bis Blvd Arago, F-75014 Paris, France
[4] Space Science Department, European Space Agency, Keplerlaan 1, 2200 AG Noordwijk, Netherlands
[5] Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, Netherlands
[6] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
[7] Lab. d'Astrophysique, Ecole Polytechn. Féd. de Lausanne (EPFL), Observatoire, CH-1290 Sauverny, Switzerland
[8] Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, AZ 86001, USA

E-mail contact: manderse *at* rssd.esa.int

We present deep Hubble Space Telescope (HST) NICMOS 2 F160W band observations of the central 56"×57" (14pc×14.25pc) region around R136 in the starburst cluster 30 Dor (NGC 2070) located in the Large Magellanic Cloud. Our aim is to derive the stellar Initial Mass Function (IMF) down to ∼1 $M_\odot$ in order to test whether the IMF in a massive metal–poor cluster is similar to that observed in nearby young clusters and the field in our Galaxy. We estimate the mean age of the cluster to be 3 Myr by combining our F160W photometry with previously obtained HST WFPC2 optical F555W and F814W band photometry and comparing the stellar locus in the color–magnitude diagram with main sequence and pre–main sequence isochrones. The color–magnitude diagrams show the presence of differential extinction and possibly an age spread of a few Myr. We convert the magnitudes into masses adopting both a single mean age of 3 Myr isochrone and a constant star formation history from 2 to 4 Myr. We derive the IMF after correcting for incompleteness due to crowding. The faintest stars detected have a mass of 0.5 $M_\odot$ and the data are more than 50% complete outside a radius of 5 pc down to a mass limit of 1.1 $M_\odot$ for 3 Myr old objects. We find an IMF of $\frac{dN}{d\log M} \propto M^{-1.20\pm0.2}$ over the mass range 1.1–20 $M_\odot$ only slightly shallower than a Salpeter IMF. In particular, we find no strong evidence for a flattening of the IMF down to 1.1 $M_\odot$ at a distance of 5 pc from the center, in contrast to a flattening at 2 $M_\odot$ at a radius of 2 pc, reported in a previous optical HST study. We examine several possible reasons for the different results including the possible presence of mass segregation and the effects of differential extinction, particularly for the pre–main sequence sources. If the IMF determined here applies to the whole cluster, the cluster would be massive enough to remain bound and evolve into a relatively low–mass globular cluster.

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Formation and survival of water vapor in the terrestrial planet-forming region

Thomas J. Bethell[1] and Edwin A. Bergin[1]

[1] Dept. of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA

E-mail contact: tbethell *at* umich.edu

Recent astronomical observations have revealed what may prove to be the ubiquity of water vapor during the early stages of planet formation. We present a simple mechanism showing how water vapor forms in situ and is capable of shielding itself from molecule-destroying stellar radiation. The absorption of this radiation by water can control the thermodynamics of the terrestrial planet-forming zone. Similar to the Earth's ozone layer, which shelters the chemistry of life, the water layer protects other water molecules and allows for a rich organic chemistry. The total abundance of water vapor in the natal habitable zone amounts to several thousand oceans-worth.

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Triggering Collapse of the Presolar Dense Cloud Core and Injecting Short-Lived Radioisotopes with a Shock Wave. I. Varied Shock Speeds

Alan P. Boss[1], Sandra A. Keiser[1], Sergei I. Ipatov[1,2], Elizabeth A. Myhill[1,3], and Harri A. T. Vanhala[1,4]

[1]DTM, Carnegie Institution, 5241 Broad Branch Road, NW, Washington, DC 20015-1305, USA
[2]Catholic University, Washington, DC
[3]Marymount University, Arlington, VA
[4]NCESSE, Washington, DC

E-mail contact: boss *at* dtm.ciw.edu

The discovery of decay products of a short-lived radioisotope (SLRI) in the Allende meteorite led to the hypothesis that a supernova shock wave transported freshly synthesized SLRI to the presolar dense cloud core, triggered its self-gravitational collapse, and injected the SLRI into the core. Previous multidimensional numerical calculations of the shock-cloud collision process showed that this hypothesis is plausible when the shock wave and dense cloud core are assumed to remain isothermal at $\sim$ 10 K, but not when compressional heating to $\sim$ 1000 K is assumed. Our two-dimensional models (Boss et al. 2008) with the FLASH2.5 adaptive mesh refinement (AMR) hydrodynamics code have shown that a 20 km/sec shock front can simultaneously trigger collapse of a 1 $M_\odot$ core and inject shock wave material, provided that cooling by molecular species such as H_2O, CO, and H_2 is included. Here we present the results for similar calculations with shock speeds ranging from 1 km/sec to 100 km/sec. We find that shock speeds in the range from 5 km/sec to 70 km/sec are able to trigger the collapse of a 2.2 $M_\odot$ cloud while simultaneously injecting shock wave material: lower speed shocks do not achieve injection, while higher speed shocks do not trigger sustained collapse. The calculations continue to support the shock-wave trigger hypothesis for the formation of the solar system, though the injection efficiencies in the present models are lower than desired.

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Near Infrared Spectroscopic Study of V1647 Ori

S. D. Brittain[1], T. W. Rettig[2], T. Simon[3], E. L. Gibb[4] and J. Liskowsky[1]

[1] Department of Physics and Astronomy, Clemson University, Clemson, SC 29634-0978, USA
[2] Center for Astrophysics, University of Notre Dame, Notre Dame, IN 46556, USA
[3] Eureka Scientific Inc., 1537 Kalaniwai Place, Honolulu HI 96821, USA
[4] University of Missouri at St. Louis, 8001 Natural Bridge Road, St. Louis, MO 63121, USA

E-mail contact: sbrit *at* texchange.clemson.edu

We present new high-resolution infrared echelle spectra of V1647 Ori, the young star that illuminates McNeil's nebula. From the start, V1647 Ori has been an enigmatic source that has defied classification, in some ways resembling eruptive stars of the FUor class and in other respects the EXor variables. V1647 Ori underwent an outburst in 2003 before fading back to its pre-outburst brightness in 2006. In 2008, it underwent a new outburst. In this paper we present high-resolution $K-$band and $M-$band spectra from the W. M. Keck Observatory that were acquired during the 2008 outburst. We compare the spectra to spectra acquired during the previous outburst and quiescent phases. We find that the luminosity and full width at half maximum power of Br γ increased as the star has brightened and decreased when the star faded indicating that these phases are driven by variations in the accretion rate. We also show that the temperature of the CO emission has varied with the stellar accretion rate confirming suggestions from modeling of the heating mechanisms of the inner disk (e.g. Glassgold et al. 2004). Finally we find that the lowest energy blue-shifted CO absorption lines originally reported in 2007 are no longer detected. The absence of these lines confirms the short-lived nature of the outflow launched at the start of the quiescent phase in 2006.

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Methyl cyanide as tracer of bow shocks in L1157-B1

C. Codella[1], M. Benedettini[2], M.T. Beltrán[1], F. Gueth[3], S. Viti[4], R. Bachiller[5], M. Tafalla[5], S. Cabrit[6], A. Fuente[5], and B. Lefloch[7]

[1] INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
[2] INAF, Istituto di Fisica dello Spazio Interplanetario, Via Fosso del Cavaliere 100, I-00133 Roma, Italy
[3] IRAM, 300 Rue de la Piscine, F-38406 Saint Martin d'Hères, France
[4] Department of Physics and Astronomy, University College London, Gower Street, London WC1E6BT, UK
[5] Observatorio Astrónomico Nacional (IGN), Alfonso XII, E-28014 Madrid, Spai
[6] LERMA, UMR 8112 du CNRS, Observatoire de Paris, 61 Av. de l'Observatoire, 75014 Paris, France
[7] Laboratoire d'Astrophysique de l'Observatoire de Grenoble, BP 53, 38041 Grenoble Cedex, France

E-mail contact: codella *at* arcetri.astro.it

Context: L1157-mm is a low-mass protostar driving an outflow which is considered the proto-type of the so-called chemically active outflows. In particular, the blue-shifted lobe B1 stands out for its rich mm-wave spectrum.
Aims: Our aim is to infer the physical conditions of the molecular gas within L1157-B1.
Methods: We carried out $CH_3CN(8_K–7_K)$ observations at 2mm with the IRAM Plateau de Bure Interferometer to map L1157-B1.
Results: The CH_3CN image shows a clumpy structure superimposed to the classical B1 arch-like shape, displaying a unique continuous structure tracing the propagation of a large bow shock. The CH_3CN spatial distribution well agrees with that of CH_3OH, one of the most abundant species evaporated from dust grain mantles. Thanks to the present CH_3CN observations at unprecedented spatial resolution, we determine for the first time the temperature distribution of the B1 bow shock. We obtain values between 57 and 132 K, with the highest temperature at the shock apex, thus confirming the association of CH_3CN with gas affected by the passage of a shock wave. The N_{CH_3CN} column densities are $\simeq$ 8–40 10^{12} cm^{-2}, depending on the position, leading to CH_3CN/CH_3OH abundance ratios $\simeq$ 0.2–1.3 10^{-3}, i.e. values on average smaller than those found in hot-corinos. This suggests that a significant amount of CH_3CN is formed in the gas phase: in the shocked L1157-B1 regions the CH_3CN abundance may not have reached its maximum yet.

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http://www.arcetri.astro.it/∼codella/papers/ch3cn.ps.gz

IPHAS and the symbiotic stars. II. New discoveries and a sample of the most common mimics

Romano Corradi[1] M. Valentini[3,4], U. Munari[3], J.E. Drew[5], E.R. Rodriguez-Flores[6,1], K. Viironen[1,2], R. Greimel[7], M. Santander-Garcia[8,1,2], L. Sabin[9], A. Mampaso[1,2], Q. Parker[10,11], K. De Pew[10], S.E. Sale[12], Y.C. Unruh[12], J.S. Vink[13], P. Rodriguez-Gil[8,1,2], M.J. Barlow[14], D.J. Lennon[15], P.J. Groot[16], C. Giammanco[1,2], A.A. Zijlstra[17], N.A. Walton[18]

[1] Instituto de Astrofisica de Canarias, Tenerife, Spain
[2] Departamento de Astrofisica, Universidad de La Laguna, E-38205 La Laguna, Tenerife, Spain
[3] INAF, Osservatorio Astronomico di Padova, via dell'Osservatorio 8, 36012 Asiago (VI), Italy
[4] Department of Astronomy, University of Padova, Asiago Astrophysical Observatory, 36012 Asiago (VI), Italy
[5] Centre for Astrophysics Research, STRI, University of Hertfordshire, College Lane, Hatfield, AL10 9AB, UK
[6] Instituto de Geofisica y Astronomia, Calle 212, N. 2906, CP 11600, La Habana, Cuba
[7] Institut fur Physik, Karl-Franzen Universitat Graz, Universitaatsplatz 5, 8010 Graz, Austria
[8] Isaac Newton Group of Telescopes, Apart. de Correos 321, 38700 Santa Cruz de la Palma, Spain
[9] Jodrell Bank Centre for Astrophysics, Alan Turing Building, University of Manchester, Manchester, M13 9PL, UK
[10] Department of Physics, Macquarie University, Sydney, NSW 2109, Australia
[11] Anglo-Australian Observatory, PO Box 296, Epping, NSW 1710, Australia
[12] Astrophysics Group, Imperial College of Science, Blackett Laboratory, Prince Consort Road, London SW7 2AZ, UK
[13] Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland
[14] Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK
[15] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[16] Department of Astrophysics, IMAPP, Radboud University Nijmegen, PO Box 9010, 6500 Gl Nijmegen, the Nether-

lands
[17] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, Oxford Street, Manchester M13 9PL, UK
[18] Institute of Astronomy, Cambridge University, Madingley Road, Cambridge, CB3 0HA, UK

E-mail contact: rcorradi *at* iac.es

Knowledge of the total population of symbiotic stars in the Galaxy is important for understanding basic aspects of stellar evolution in interacting binaries and the relevance of this class of objects in the formation of supernovae of type Ia. In a previous paper, we presented the selection criteria needed to search for symbiotic stars in IPHAS, the INT Halpha survey of the Northern Galactic plane. IPHAS gives us the opportunity to make a systematic, complete search for symbiotic stars in a magnitude-limited volume. Follow-up spectroscopy at different telescopes worldwide of a sample of sixty two symbiotic star candidates from paper I is presented. Seven out of nineteen S-type candidates observed spectroscopically are confirmed to be genuine symbiotic stars. The spectral type of their red giant components, as well as reddening and distance, were computed by modelling the spectra. Only one new D-type symbiotic system, out of forty-three candidates observed, was found. This was as expected (see discussion in our paper on the selection criteria). The object shows evidence for a high density outflow expanding at a speed larger than 65 km/s. Most of the other candidates are lightly reddened classical T Tauri stars and more highly reddened young stellar objects that may be either more massive young stars of HAeBe type or classical Be stars. In addition, a few notable objects have been found, such as three new Wolf-Rayet stars and two relatively high-luminosity evolved massive stars. We also found a helium-rich source, possibly a dense ejecta hiding a WR star, which is surrounded by a large ionized nebula. These spectroscopic data allow us to refine the selection criteria for symbiotic stars in the IPHAS survey and, more generally, to better understand the behaviour of different Halpha emitters in the IPHAS and 2MASS colour-colour diagrams.

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The Effects of Opacity on Gravitational Stability in Protoplanetary Discs

Peter Cossins[1], Giuseppe Lodato[1,2] and Cathie Clarke[3]

[1] University of Leicester, Leicester, UK
[2] Università Degli Studi de Milano, Milan, Italy
[3] Institute of Astronomy, Cambridge, UK

E-mail contact: peter.cossins *at* astro.le.ac.uk

In this paper we consider the effects of opacity regimes on the stability of self-gravitating protoplanetary discs to fragmentation into bound objects. Using a self-consistent 1-D viscous disc model, we show that the ratio of local cooling to dynamical timescales $\Omega t_{\rm cool}$ has a strong dependence on the local temperature. We investigate the effects of temperature-dependent cooling functions on the disc gravitational stability through controlled numerical experiments using an SPH code. We find that such cooling functions raise the susceptibilty of discs to fragmentation through the influence of temperature perturbations – the average value of $\Omega t_{\rm cool}$ has to increase to prevent local variability leading to collapse. We find the effects of temperature-dependence to be most significant in the 'opacity gap' associated with dust sublimation, where the average value of $\Omega t_{\rm cool}$ at fragmentation is increased by over an order of magnitude. We then use this result to predict where protoplanetary discs will fragment into bound objects in terms of radius and accretion rate, and find that for radii $\lesssim 10 AU$ the accretion rate at fragmentation is reduced from $\sim 10^{-3}$ to $\sim 10^{-4}$ $M_\odot$ yr^{-1}. We also find that the stability of discs with accretion rates $\lesssim 10^{-7}$ $M_\odot$ yr^{-1} at radii $\gtrsim 50 AU$ is enhanced by a lower background temperature.

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Search for associations containing young stars (SACY) - III. Ages and Li abundances

L. da Silva [1], C. A. O. Torres[2], R. de la Reza[1], G. R. Quast[2], C. H. F. Melo[3] and M. F. Sterzik[4]

[1] Observatório Nacional, Rua General José Cristino 77, São Cristovão, 20921-400, Rio de Janeiro, Brazil
[2] Laboratório Nacional de Astrofisica, Itajubá, MG, Brazil
[3] European Southern Observatory, Garching, Germany

[4] European Southern Observatory, Santiago, Chile

E-mail contact: licio *at* on.br

Our study is a follow-up of the SACY project, an extended high spectral resolution survey of more than two thousand optical counterparts to X-ray sources in the Southern Hemisphere targeted to search for young nearby association. Nine associations have either been newly identified, or have had their member list revised. Groups belonging to the Sco-Cen-Oph complex are not considered in the present study. These nine associations, with ages of between about 6 Myr and 70 Myr, form an excellent sample to study the Li depletion in the pre-main sequence (PMS) evolution. In the present paper, we investigate the use of Li abundances as an independent clock to constrain the PMS evolution. Using our measurements of the equivalent widths of the Li resonance line and assuming fixed metallicities and microturbulence, we calculated the LTE Li abundances for 376 members of various young associations. In addition, we considered the effects of their projected stellar rotation. We present the Li depletion as a function of age in the first hundred million years for the first time for the most extended sample of Li abundances in young stellar associations. A clear Li depletion can be measured in the temperature range from 5000 K to 3500 K for the age span covered by the nine associations studied in this paper. The age sequence based on the Li-clock agrees well with the isochronal ages, the ϵCha association being the only possible exception. The lithium depletion patterns for the associations presented here resemble those of the young open clusters with similar ages, strengthening the notion that the members proposed for these loose young associations have indeed a common physical origin. The observed scatter in the Li abundances hampers the use of Li in determining reliable ages for individual stars. For velocities above $20\,\mathrm{km\,s^{-1}}$, rotation seems to play an important role in inhibiting the Li depletion.

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The interaction of an O star wind with an HH jet

A. Esquivel[1], A. Raga[1], J. Canto[2] and A. Rodriguez-Gonzalez[1]

[1] ICN, UNAM, Ap. 70-543, 04510 DF, Mexico
[2] IA, UNAM, Ap. 70-468, 04510 DF, Mexico

E-mail contact: esquivel *at* nuceares.unam.mx

Herbig-Haro jets ejected from young, low mass stars in the proximity of O/B stars will interact with the more or less isotropic winds from the more massive stars. An example of this are the jets from the stars within the proplyds near θ-Orionis. In this paper, we consider the interaction of an externally photoionized HH jet with an isotropic wind ejected from the ionizing photon source. We study this problem through numerical simulations, allowing us to obtain predictions of the detailed structure of the flow and predictions of Hα intensity maps. This is a natural extension of a previously developed analytic model for the interaction between a jet and an isotropic stellar wind. We present 3D simulations of a bipolar HH jet interacting with an isotropic wind from a massive star, assuming that the radiation from the star photoionizes all of the flow. We explore different possible flow configuration, exploring a limited set of jet and stellar wind parameters and orientations of the jet/counterjet ejection. We have computed 6 models, two of which also include a time-variability in the jet velocity. We compare the locus of the computed jet/counterjet systems with the analytic model, and find very good agreement except for cases in which the direction of the jet (or the counterjet) approaches the direction to the wind source (i. e., the O star). For the models with variable ejection velocities, we find that the internal working surfaces follow straighter trajectories (and the inter-working surface segments more curved trajectories) than the analytic, steady jet model.

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REM near-IR and optical photometric monitoring of Pre-Main Sequence Stars in Orion. Rotation periods and starspot parameters

A. Frasca[1], E. Covino[2], L. Spezzi[1,3], J.M. Alcalá[2], E. Marilli[1], G. Fűrész[4] and D. Gandolfi[1,5]

[1] INAF, Osservatorio Astrofisico di Catania, via S. Sofia, 78, 95123 Catania, Italy
[2] INAF, Osservatorio Astronomico di Capodimonte, via Moiariello 16, 80131 Napoli, Italy
[3] European Space Agency (ESTEC), PO Box 299, 2200 AG Noordwijk, The Netherlands
[4] Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[5] Thüringer Landessternwarte Tautenburg, Sternwarte 5, 07778 Tautenburg, Germany

E-mail contact: antonio.frasca *at* oact.inaf.it

We performed an intensive photometric monitoring of the PMS stars falling in a field of about $10' \times 10'$ in the vicinity of the Orion Nebula Cluster (ONC), also containing the BD eclipsing system 2MASS J05352184-0546085. Photometric data were collected between November 2006 and January 2007 with the REM telescope in the $VRIJHK'$ bands. The largest number of observations is in the I band (about 2700 images) and in J and H bands (about 500 images in each filter). From the observed rotational modulation, induced by the presence of surface inhomogeneities, we derived the rotation periods. The long time-baseline (nearly three months) allowed us to detect rotation periods, also for the slowest rotators, with sufficient accuracy ($\Delta P/P < 2\%$). The analysis of the spectral energy distributions and, for some stars, of high-resolution spectra provided us with the main stellar parameters (luminosity, effective temperature, mass, age, and $v \sin i$) which are essential for the discussion of our results. Moreover, the simultaneous observations in six bands, spanning from optical to near-infrared wavelengths, enabled us to derive the starspot properties for these very young low-mass stars.
In total, we were able to determine the rotation periods for 29 stars, spanning from about 0.6 to 20 days. Thanks to the relatively long time-baseline of our photometry, we derived periods for 16 stars and improved previous determinations for the other 13. We also report the serendipitous detection of two strong flares in two of these objects. In most cases, the light-curve amplitudes decrease progressively from the R to H band as expected for cool starspots, while in a few cases, they can only be modelled by the presence of hot spots, presumably ascribable to magnetospheric accretion. The application of our own spot model to the simultaneous light curves in different bands allowed us to deduce the spot parameters and particularly to disentangle the spot temperature and size effects on the observed light curves.

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Gas Accretion from a Circumbinary Disk

Tomoyuki Hanawa[1], Yasuhiro Ochi[2] and Koichi Ando[2]

[1] Center for Frontier Science, Chiba University, Inage-ku, Chiba, 263-8522, Japan
[2] Graduate School of Science, Chiba University, Inage-ku, Chiba, 263-8522, Japan

E-mail contact: hanawa *at* cfs.chiba-u.ac.jp

A new computational scheme is developed to study gas accretion from a circumbinary disk. The scheme decomposes the gas velocity into two components one of which denotes the Keplerian rotation and the other of which does the deviation from it. This scheme enables us to solve the centrifugal balance of a gas disk against gravity with better accuracy, since the former inertia force cancels the gravity. It is applied to circumbinary disk rotating around binary of which primary and secondary has mass ratio, 1.4:0.95. The gravity is reduced artificially softened only in small circular regions around the primary and secondary. The radii are 7% of the binary separation and much smaller than those in the previous grid based simulations. 7 Models are constructed to study dependence on the gas temperature and the initial inner radius of the disk. The gas accretion shows both fast and slow time variations while the binary is assumed to have a circular orbit. The time variation is due to oscillation of spiral arms in the circumbinary disk. The masses of primary and secondary disks increase while oscillating appreciably. The mass accretion rate tends to be higher for the primary disk although the secondary disk has a higher accretion rate in certain periods. The primary disk is perturbed intensely by the impact of gas flow so that the outer part is removed. The secondary disk is quiet in most of time on the contrary. Both the primary and secondary disks have traveling spiral waves which transfer angular momentum within them.

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Algorithmic comparisons of decaying, isothermal, supersonic turbulence

S. Kitsionas[1], C. Federrath[2,3], R. S. Klessen[1,2], W. Schmidt[4], D. J. Price[5,6], L. J. Dursi[7], M. Gritschneder[8], S. Walch[8,9], R. Piontek[1], Jongsoo Kim[10], A.-K. Jappsen[1,7,9], P. Ciecielag[8,11] and M.-M. Mac Low[12]

[1] Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany
[2] Institut für Theoretische Astrophysik, Universität Heidelberg, Albert-Ueberle-Str. 2, D-69120 Heidelberg, Germany
[3] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

[4] Lehrstuhl für Astronomie, Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany
[5] School of Physics, University of Exeter, Stocker Road, EX4 4QL Exeter, U.K.
[6] CSPA, School of Mathematical Sciences, Monash University, Clayton Vic 3168, Australia
[7] Canadian Institute for Theoretical Astrophysics, University of Toronto, 60 St. George Street, Toronto, ON, M5S 3H8, Canada
[8] Universitäts-Sternwarte München, Scheinerstr. 1, D-81679 München, Germany
[9] School of Physics & Astronomy, Cardiff University, 5 The Parade, CF24 3AA Cardiff, U.K.
[1]0 Korea Astronomy and Space Science Institute, 61-1 Hwaam-dong, Yuseong-gu, Daejeon, 305-348, Republic of Korea
[1]1 N. Copernicus Astronomical Center, Bartycka 18, 00-716 Warsaw, Poland
[1]2 American Museum of Natural History, Department of Astrophysics, Central Park West at 79th Street, New York, NY, 10024-5192, U.S.A.

E-mail contact: chfeder *at* ita.uni-heidelberg.de

Simulations of astrophysical turbulence have reached such a level of sophistication that quantitative results are now starting to emerge. However, contradicting results have been reported in the literature with respect to the performance of the numerical techniques employed for its study and their relevance to the physical systems modelled. We aim at characterising the performance of a variety of hydrodynamics codes including different particle-based and grid-based techniques on the modelling of decaying supersonic turbulence. This is the first such large-scale comparison ever conducted. We modelled driven, compressible, supersonic, isothermal turbulence with an RMS Mach number of $M_{\rm rms} \sim 4$, and then let it decay in the absence of gravity, using runs performed with four different grid codes (`ENZO`, `FLASH`, `TVD`, `ZEUS`) and three different SPH codes (`GADGET`, `PHANTOM`, `VINE`). We additionally analysed two calculations denoted as `PHANTOM A` and `PHANTOM B` using two different implementations of artificial viscosity in `PHANTOM`. We analysed the results of our numerical experiments using volume-averaged quantities like the RMS Mach number, volume- and density-weighted velocity Fourier spectrum functions, and probability distribution functions of density, velocity, and velocity derivatives. Our analysis indicates that grid codes tend to be less dissipative than SPH codes, though details of the techniques used can make large differences in both cases. For example, the Morris & Monaghan viscosity implementation for SPH results in less dissipation (`PHANTOM B` and `VINE` versus `GADGET` and `PHANTOM A`). For grid codes, using a smaller diffusion parameter leads to less dissipation, but results in a larger bottleneck effect (our `ENZO` versus `FLASH` runs). As a general result, we find that by using a similar number of resolution elements N for each spatial direction means that all codes (both grid-based and particle-based) show encouraging similarity of all statistical quantities for isotropic supersonic turbulence on spatial scales $k < N/32$ (all scales resolved by more than 32 grid cells), while scales smaller than that are significantly affected by the specific implementation of the algorithm for solving the equations of hydrodynamics. At comparable numerical resolution ($N_{\rm particles} \approx N_{\rm cells}$), the SPH runs were on average about ten times more computationally intensive than the grid runs, although with variations of up to a factor of ten between the different SPH runs and between the different grid runs. At the resolutions employed here, the ability to model supersonic to transonic flows is comparable across the various codes used in this study.

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Revealing the sub-AU asymmetries of the inner dust rim in the disk around the Herbig Ae star R CrA

Stefan Kraus[1], Karl-Heinz Hofmann[1], Fabien Malbet[2], Anthony Meilland[3,1], Antonella Natta[4], Dieter Schertl[1], Philippe Stee[3] and Gerd Weigelt[1]

[1] Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[2] Laboratoire d'Astrophysique de Grenoble, UMR 5571 Université Joseph Fourier/CNRS, BP 53, 38041 Grenoble Cedex 9, France
[3] UMR 6525 H. Fizeau, Univ. Nice Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, Av. Copernic, F-06130 Grasse, France
[4] INAF-Osservatorio Astrofisico di Arcetri, Largo Fermi 5, 50125 Firenze, Italy

E-mail contact: skraus *at* mpifr.de

Context: Unveiling the structure of the disks around intermediate-mass pre-main-sequence stars (Herbig Ae/Be stars)

is essential for our understanding of the star and planet formation process. In particular, models predict that in the innermost AU around the star, the dust disk forms a "puffed-up" inner rim, which should result in a strongly asymmetric brightness distribution for disks seen under intermediate inclination.
Aims: Our aim is to constrain the sub-AU geometry of the inner disk around the Herbig Ae star R CrA and search for the predicted asymmetries.
Methods: Using the VLTI/AMBER long-baseline interferometer, we obtained 24 near-infrared (H- and K-band) spectro-interferometric observations on R CrA. Observing with three telescopes in a linear array configuration, each data set samples three equally spaced points in the visibility function, providing direct information about the radial intensity profile. In addition, the observations cover a wide position angle range ($\sim 97°$), also probing the position angle dependence of the source brightness distribution.
Results: In the derived visibility function, we detect the signatures of an extended (Gaussian FWHM ~ 25 mas) and a compact component (Gaussian FWHM ~ 5.8 mas), with the compact component contributing about two-thirds of the total flux (both in H- and K-band). The brightness distribution is highly asymmetric, as indicated by the strong closure phases (up to $\sim 40°$) and the detected position angle dependence of the visibilities and closure phases. To interpret these asymmetries, we employ various geometric as well as physical models, including a binary model, a skewed ring model, and a puffed-up inner rim model with a vertical or curved rim shape. For the binary and vertical rim model, no acceptable fits could be obtained. On the other hand, the skewed ring model and the curved puffed-up inner rim model allow us to simultaneously reproduce the measured visibilities and closure phases. From these models we derive the location of the dust sublimation radius (~ 0.4 AU), the disk inclination angle ($\sim 35°$), and a north-southern disk orientation (PA$\sim$180-190°). Our curved puffed-up rim model can reasonably well reproduce the interferometric observables and the SED simultaneously and suggests a luminosity of $\sim 29\ L_\odot$ and the presence of relatively large ($\gtrsim$1.2 μm) Silicate dust grains. Our study also reveals significant deviations between the measured interferometric observables and the employed puffed-up inner rim models, providing important constraints for future refinements of these theoretical models. Perpendicular to the disk, two bow shock-like structures appear in the associated reflection nebula NGC 6729, suggesting that the detected sub-AU size disk is the driving engine of a large-scale outflow.
Conclusions: Detecting, for the first time, strong non-localized asymmetries in the inner regions of a Herbig Ae disk, our study supports the existence of a puffed-up inner rim in YSO disks.

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http://www.skraus.eu/papers/rcra.pdf

Magnetic Field Structure of the HH 1-2 Region: Near-Infrared Polarimetry of Point-Like Sources

Jungmi Kwon[1,2], Minho Choi[2], Soojong Pak[1], Ryo Kandori[3], Motohide Tamura[3], Tetsuya Nagata[4] and Shuji Sato[5]

[1] Department of Astronomy and Space Science, Kyung Hee University, South Korea
[2] International Center for Astrophysics, Korea Astronomy and Space Science Institute, South Korea
[3] National Astronomical Observatory of Japan, Japan
[4] Department of Astronomy, Kyoto University, Japan
[5] Department of Astrophysics, Nagoya University, Japan

E-mail contact: soojong *at* khu.ac.kr

The HH 1–2 region in the L1641 molecular cloud was observed in the near-IR J, H, and K_s bands, and imaging polarimetry was performed. Seventy six point-like sources were detected in all three bands. The near-IR polarizations of these sources seem to be caused mostly by the dichroic extinction. Using a color-color diagram, reddened sources with little infrared excess were selected to trace the magnetic field structure of the molecular cloud. The mean polarization position angle of these sources is about 111 deg, which is interpreted as the projected direction of the magnetic field in the observed region of the cloud. The distribution of the polarization angle has a dispersion of about 11 deg, which is smaller than what was measured in previous studies. This small dispersion gives a rough estimate of the strength of the magnetic field to be about 130 μG and suggests that the global magnetic field in this region is quite regular and straight. In contrast, the outflows driven by young stellar objects in this region seem to have no preferred orientation. This discrepancy suggests that the magnetic field in the L1641 molecular cloud does not dictate the orientation of the protostars forming inside.

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Near-IR integral field spectroscopy of ionizing stars and young stellar objects on the borders of HII regions

F. Martins[1], M. Pomares[2], L. Deharveng[2], A. Zavagno[2] and J.-C. Bouret[2]

[1] GRAAL-CNRS
[2] LAM-OAMP

E-mail contact: martins *at* graal.univ-montp2.fr

We present near-IR SINFONI observations of three Galactic HII regions: RCW79, RCW82 and RCW120. We identify the ionizing stars of each region: they are early to late O stars, close to the main sequence. We derive their stellar and wind properties using atmosphere models computed with the code CMFGEN. The cluster ionizing RCW79 formed 2.3±0.5 Myr ago. Similar ages are estimated, albeit with a larger uncertainty, for the ionizing stars of the other two regions. In RCW79 the mechanical wind luminosity represents only 0.1% of the ionizing luminosity, questioning the influence of stellar winds on the dynamics of the the HII region. The young stellar objects show four main types of spectral features: H2 emission, Brγ emission, CO bandheads emission and CO bandheads absorption. These features are typical of young stellar objects surrounded by disks and/or envelopes. The radial velocities of most YSOs are consistent with that of the ionized gas, firmly establishing that star formation is taking place on the borders of the HII regions. Outflows are detected in a few YSOs. All YSOs have moderate to strong near-IR excess. In the [24] versus K-[24] diagram, the majority of the sources dominated by H2 emission lines stand out as redder and brighter than the rest of the YSOs. Their H2 emission is mainly due to shocks. We tentatively propose that they represent an earlier phase of evolution compared to sources dominated by Brγ and CO bandheads. We suggest that they still possess a dense envelope in which jets or winds create shocks. The other YSOs have partly lost their envelopes and show signatures of accretion disks.

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A Feature Movie of SiO Emission 20-100 AU from the Massive Young Stellar Object Orion Source I

L. D. Matthews[1,2], L. J. Greenhill[1], C. Goddi[1], C. J. Chandler[3], E. M. L. Humphreys[1] and M. Kunz[3,4]

[1] Harvard-Smithsonian Center for Astrophysics, USA
[2] MIT Haystack Observatory, USA
[3] National Radio Astronomy Observatory, USA
[4] University of Illinois, USA

E-mail contact: lmatthew *at* haystack.mit.edu

We present multi-epoch Very Long Baseline Array (VLBA) imaging of the ^{28}SiO v=1 and v=2, J=1-0 maser emission toward the massive young stellar object (YSO) Orion Source I. Both SiO transitions were observed simultaneously with an angular resolution of ∼0.5 mas (∼0.2 AU for d=414 pc) and a spectral resolution of ∼0.2 km s^{-1}. Here we explore the global properties and kinematics of the emission through two 19-epoch animated movies spanning 21 months (2001 March 19 to 2002 December 10). These movies provide the most detailed view to date of the dynamics and temporal evolution of molecular material within ∼20-100 AU of a massive ($\gtrsim 8 M_\odot$) YSO. As in previous studies, we find that the bulk of the SiO masers surrounding Source I lie in an X-shaped locus; the emission in the South and East arms is predominantly blueshifted and emission in the North and West is predominantly redshifted. In addition, bridges of intermediate-velocity emission are observed connecting the red and blue sides of the emission distribution. We have measured proper motions of over 1000 individual maser features and find that these motions are characterized by a combination of radially outward migrations along the four main maser-emitting arms and motions tangent to the intermediate-velocity bridges. We interpret the SiO masers as arising from a wide-angle bipolar wind emanating from a rotating, edge-on disk. The detection of maser features along extended, curved filaments suggests that magnetic fields may play a role in launching and/or shaping the wind. Our observations appear to support a picture in which

stars with masses as high as at least $8M_{\odot}$ form via disk-mediated accretion. However, we cannot yet rule out that the Source I disk may have been formed or altered following a recent close encounter.

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Will the Large Synoptic Survey Telescope detect extra-solar planetesimals entering the solar system?

Amaya Moro-Martin[1], Edwin L. Turner[2] and Abraham Loeb[3]

[1] Centro de Astrobiologia (CSIC-INTA), 28850 Torrejon de Ardoz, Madrid, Spain
[2] Princeton University Observatory, Princeton, NJ 08544, USA
[3] Harvard University, Center for Astrophysics, MS 51, 60 Garden Street, Cambridge MA 02138, USA

E-mail contact: amaya *at* astro.princeton.edu

Planetesimal formation is a common by-product of the star formation process. Taking the dynamical history of the solar system as a guideline – in which the planetesimal belts were heavily depleted due to gravitational perturbation with the giant planets – and assuming similar processes have take place in other planetary systems, one would expect the interstellar space to be filled with extra-solar planetesimals. However, not a single one of these objects has been detected so far entering the solar system, even though it would clearly be distinguishable from a solar system comet due to its highly hyperbolic orbit. The *Large Synoptic Survey Telescope* will provide wide coverage maps of the sky to a very high sensitivity, ideal to detect moving objects like comets, both active and inactive. In anticipation of these observations, we estimate how many *inactive* "interstellar comets" might be detected during the duration of the survey. The calculation takes into account estimates (from observations and models) of the number density of stars, the amount of solids available to form planetesimals, the frequency of planet and planetesimal formation, the efficiency of planetesimal ejection, and the possible size distribution of these small bodies.

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Herbig-Haro flows in 3D: the HH 83 jet

T.A. Movsessian[1], T.Yu. Magakian[1], A.V. Moiseev[2] and M.D. Smith[3]

[1] Byurakan Astrophysical Observatory, 378433 Aragatsotn reg., Armenia
[2] Special Astrophysical Observatory, N.Arkhyz, Karachaevo-Cherkesia, 369167, Russia
[3] Centre for Astrophysics & Planetary Science, University of Kent, Canterbury CT2 7NH, U.K

E-mail contact: tigmov *at* web.am, tigmag *at* sci.am

The kinematics of the HH 83 optical outflow, located in the L 1641 molecular cloud, are investigated. Observations were carried out with the Fabry-Perot scanning interferometer on the 6-meter telescope of the Special Astrophysical Observatory. The Hα emission line was scanned with a spectral resolution of R = 8200. The radial velocity along the jet increases with distance from the source, confirming previous results. It also shows lower amplitude variations which are not correlated with intensity. Both the spatial width of the jet as well as the FWHM of the Hα emission line in the jet tend to decrease with distance from the source. The velocity field across the jet demonstrates a decrease from the center to the edges as well as some evidence for a transverse velocity gradient. The blue-shifted bow shock is separated spatially and spectrally into two distinct features, divided by about 2 arcsec and 250 $\mathrm{km\,s^{-1}}$, accordingly. Evidence is provided that these split features correspond to forward and reverse shocks caused by a rapid pressure increase as the jet begins a new oblique impact on the surrounding medium. Radial velocity variations lengthwise and transverse to the jet axis are discussed. Linear extrapolation of the jet velocity up to the location of the terminal shock region yields the radial velocity of the reverse jet shock. The data are consistent with an abrupt outburst about one thousand years ago which ejected material with total speeds of up to 400 $\mathrm{km\,s^{-1}}$.

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A Spitzer Census of Transitional Protoplanetary Disks with AU-Scale Inner Holes

James Muzerolle[1], Lori E. Allen[2], S. Thomas Megeath[3], Jesus Hernandez[4] and Robert A. Gutermuth[5]

[1] Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218, USA
[2] National Optical Astronomy Observatory, 950 N. Cherry Ave., Tucson, AZ 85719, USA
[3] Ritter Observatory, Department of Physics and Astronomy, University of Toledo, 2801 W. Bancroft Ave., Toledo, OH 43606, USA
[4] Centro de Investigaciones de Astronomía, Apdo. Postal 264, Mérida 5101-A, Venezuela
[5] Five Colleges Astronomy Dept., Smith College, Northampton, MA 01063, USA

E-mail contact: muzerol *at* stsci.edu

Protoplanetary disks with AU-scale inner clearings, often referred to as transitional disks, provide a unique sample for understanding disk dissipation mechanisms and possible connections to planet formation. Observations of young stellar clusters with the *Spitzer* Space Telescope have amassed mid-infrared spectral energy distributions for thousands of star-disk systems from which transition disks can be identified. From a sample of 8 relatively nearby young regions ($d \leq 400$ pc), we have identified about 20 such objects, which we term "classical" transition disks, spanning a wide range of stellar age and mass. We employed strict infrared continuum criteria to limit ambiguity: an 8 to 24 μm spectral slope limit ($\alpha > 0$) to select for robust optically thick outer disks, and 3.6 to 5.8 μm spectral slope and 5.8 μm continuum excess limits to select for optically thin or zero continuum excess from the inner few AU of the disks. We also identified two additional categories representing more ambiguous cases: "warm excess" objects with transition-like spectral energy distributions but moderate excess at 5.8 μm, and "weak excess" objects with smaller 24 μm excess that may be optically thin or exhibit advanced dust grain growth and settling. From existing Hα emission measurements, we find evidence for different accretion activity among the three categories, with a majority of the classical and warm excess transition objects still accreting gas through their inner holes and onto the central stars, while a smaller fraction of the weak transition objects are accreting at detectable rates. We find a possible age dependence to the frequency of classical transition objects, with fractions relative to the total population of disks in a given region of a few percent at 1-2 Myr rising to 10-20% at 3-10 Myr. The trend is even stronger if the weak and warm excess objects are included. This relationship may be due to a dependence of the outer disk clearing timescale with stellar age, suggesting a variety of clearing mechanisms working at different times, or it may reflect that a smaller fraction of all disks actually undergo an inner clearing phase at younger ages. Classical transition disks appear to be less common, and weak transition disks more common, around lower-mass stars ($M \leq 0.3 M_{\odot}$), which we suggest may be a further indicator of the stellar mass-dependent disk evolution that has been seen in previous studies. The difference in number statistics and accretion activity between the two classes further suggests that they are not connected but rather represent distinct evolutionary outcomes for disks.

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Stellar interactions in dense and sparse star clusters

C. Olczak[1,2,3], S. Pfalzner[1] and A. Eckart[1,4]

[1] I. Physikalisches Institut, Universität zu Köln, Zülpicher Str.77, 50937 Köln, Germany
[2] National Astronomical Observatories of China (NAOC), Chinese Academy of Sciences (CAS), 20A Datun Rd., Chaoyang District, Beijing 100012, P. R. China
[3] The Kavli Institute for Astronomy and Astrophysics (KIAA), Peking University, Yi He Yuan Lu 5, Hai Dian Qu, Beijing 100871, P. R. China
[4] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

E-mail contact: olczak *at* ph1.uni-koeln.de

Stellar encounters potentially affect the evolution of the protoplanetary discs in the Orion Nebula Cluster (ONC). However, the role of encounters in other cluster environments is less known. We investigate the effect of the encounter-induced disc-mass loss in different cluster environments. Starting from an ONC-like cluster we vary the cluster size and density to determine the correlation of collision time scale and disc-mass loss. We use the NBODY6++ code to model the dynamics of these clusters and analyze the effect of star-disc encounters. We find that the disc-mass loss depends strongly on the cluster density but remains rather unaffected by the size of the stellar population. The essential outcome of the simulations are: i) Even in clusters four times sparser than the ONC the effect of encounters

is still apparent. ii) The density of the ONC itself marks a threshold: in less dense and less massive clusters it is the massive stars that dominate the encounter-induced disc-mass loss whereas in denser and more massive clusters the low-mass stars play the major role for the disc mass removal. It seems that in the central regions of young dense star clusters – the common sites of star formation – stellar encounters do affect the evolution of the protoplanetary discs. With higher cluster density low-mass stars become more heavily involved in this process. This finding allows for the extrapolation towards extreme stellar systems: in case of the Arches cluster one would expect stellar encounters to destroy the discs of most of the low- and high-mass stars in several hundred thousand years, whereas intermediate mass stars are able to retain to some extant their discs even under these harsh environmental conditions.

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Ice chemistry in embedded young stellar objects in the Large Magellanic Cloud

J.M. Oliveira[1], J. Th. van Loon[1], C.-H. R. Chen[2], A. G. G. M. Tielens[3], G. C. Sloan[4], P. M. Woods[5], F. Kemper[5], R. Indebetouw[2], K. D. Gordon[6], M. L. Boyer[6], B. Shiao[6], S. Madden[7], A. K. Speck[8], M. Meixner[6] and M. Marengo[9]

[1] Keele University, UK
[2] U. Virginia, USA
[3] Leiden University, The Netherlands
[4] Cornell University, USA
[5] U. Manchester, UK
[6] STSci, USA
[7] CEA, France
[8] U. Missouri, USA
[9] Iowa State University, USA

E-mail contact: joana *at* astro.keele.ac.uk

We present spectroscopic observations of a sample of 15 embedded young stellar objects (YSOs) in the Large Magellanic Cloud (LMC). These observations were obtained with the *Spitzer Infrared Spectrograph* (IRS) as part of the SAGE-Spec Legacy program. We analyze the two prominent ice bands in the IRS spectral range: the bending mode of CO_2 ice at 15.2 μm and the ice band between 5 and 7 μm that includes contributions from the bending mode of water ice at 6 μm amongst other ice species. The $5-7\,\mu$m band is difficult to identify in our LMC sample due to the conspicuous presence of PAH emission superimposed onto the ice spectra. We identify water ice in the spectra of two sources; the spectrum of one of those sources also exhibits the 6.8-μm ice feature attributed in the literature to ammonium and methanol. We model the CO_2 band in detail, using the combination of laboratory ice profiles available in the literature. We find that a significant fraction ($\gtrsim 50\%$) of CO_2 ice is locked in a water-rich component, consistent with what is observed for Galactic sources. The majority of the sources in the LMC also require a pure-CO_2 contribution to the ice profile, evidence of thermal processing. There is a suggestion that CO_2 production might be enhanced in the LMC, but the size of the available sample precludes firmer conclusions. We place our results in the context of the star formation environment in the LMC.

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How Universal are the Young Cluster Sequences? - the Cases of LMC, SMC, M83 and the Antennae

S. Pfalzner[1] and A. Eckart[1]

[1] I. Physikalisches Institut, University Cologne, Germany

E-mail contact: pfalzner *at* ph1.uni-koeln.de

Recently a new analysis of cluster observations in the Milky Way found evidence that clustered star formation may work under tight constraints with respect to cluster size and density, implying the presence of just two sequences of young massive cluster. These two types of clusters each expand at different rates with cluster age. Here we investigate whether similar sequences exist in other nearby galaxies. We find that while for the extragalactic young stellar clusters the overall trend in the cluster-density scaling is quite comparable to the relation obtained for Galactic clusters, there are also possible difference. For the LMC and SMC clusters the densities are below the Galactic data points and/or the core radii are smaller than those of data points with comparable density. For M83 and the Antenna clusters the core radii are possibly comparable to the Galactic clusters but it is not clear whether they exhibit similar expansion speeds. These findings should serve as an incentive to perform more systematic observations and analysis to answer the question of a possible similarity between young galactic and extragalactic star clusters sequences.

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Dynamical Evolution of Young Embedded Clusters: A Parameter Space Survey

Eva-Marie Proszkow[1] and Fred C. Adams[1,2]

[1] Michigan Center for Theoretical Physics, Physics Department, University of Michigan, Ann Arbor, MI 48109, USA
[2] Astronomy Department, University of Michigan, Ann Arbor, MI 48109, USA

E-mail contact: fca *at* umich.edu

This paper investigates the dynamical evolution of embedded stellar clusters from the protocluster stage, through the embedded star-forming phase, and out to ages of 10 Myr — after the gas has been removed from the cluster. The relevant dynamical properties of young stellar clusters are explored over a wide range of possible star formation environments using N-body simulations. Many realizations of equivalent initial conditions are used to produce robust statistical descriptions of cluster evolution including the cluster bound fraction, radial probability distributions, as well as the distributions of close encounter distances and velocities. These cluster properties are presented as a function of parameters describing the initial configuration of the cluster, including the initial cluster membership N, initial stellar velocities, cluster radii, star formation efficiency, embedding gas dispersal time, and the degree of primordial mass segregation. The results of this parameter space survey, which includes $\sim 25,000$ simulations, provide a statistical description of cluster evolution as a function of the initial conditions. We also present a compilation of the FUV radiation fields provided by these same cluster environments. The output distributions from this study can be combined with other calculations, such as disk photoevaporation models and planetary scattering cross sections, to ascertain the effects of the cluster environment on the processes involved in planet formation.

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Search for very low-mass brown dwarfs and free-floating planetary-mass objects in Taurus

Sascha P. Quanz[1,2], Betrand Goldman[2], Thomas Henning[2], Wolfgang Brandner[2], Adam Burrows[3,4] and Lorne W. Hofstetter[5]

[1] ETH Zurich, Institute for Astronomy, Zurich, Switzerland
[2] Max Planck Institute for Astronomy, Heidelberg, Germany
[3] Department of Astronomy and Steward Observatory, University of Arizona, Tucson, USA
[4] Department of Astrophysical Sciences, Peyton Hall, Princeton University, Princeton, USA
[5] Department of Physics, Princeton University, Princeton, USA

E-mail contact: quanz *at* astro.phys.ethz.ch

The number of low-mass brown dwarfs and even free floating planetary mass objects in young nearby star-forming regions and associations is continuously increasing, offering the possibility to study the low-mass end of the IMF in greater detail. In this paper, we present six new candidates for (very) low-mass objects in the Taurus star-forming region one of which was recently discovered in parallel by Luhman et al. (2009). The underlying data we use is part of a new database from a deep near-infrared survey at the Calar Alto observatory. The survey is more than four magnitudes deeper than the 2MASS survey and covers currently 1.5 square degree. Complementary optical photometry from SDSS were available for roughly 1.0 square degree. After selection of the candidates using different color indices, additional photometry from Spitzer/IRAC was included in the analysis. In greater detail we focus on two very faint objects for which we obtained J-band spectra. Based on comparison with reference spectra we derive a spectral type of L2+/-0.5 for one object, making it the object with the latest spectral type in Taurus known today. From models we find the effective temperature to be 2080+/-140 K and the mass 5-15 Jupiter masses. For the second source the J-band spectrum does not provide a definite proof of the young, low-mass nature of the object as the expected steep water vapor absorption at 1.33 micron is not present in the data. We discuss the probability that this object might be a background giant or carbon star. If it were a young Taurus member, however, a comparison to theoretical models suggests that it lies close to or even below the deuterium burning limit (<13 Jupiter masses) as well. A first proper motion analysis for both objects shows that they are good candidates for being Taurus members.

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Mirror and point symmetries in a ballistic jet from a binary system

A. C. Raga[1], A. Esquivel[1], P. F. Velazquez[1], J. Canto[2], S. Haro-Corzo[1], A. Riera[3] and A. Rodriguez-Gonzalez[1]

[1] ICN, UNAM, Ap. 70-543, 04510 DF, Mexico

[2] IA, UNAM, Ap. 70-468, 04510 DF, Mexico

[3] Dep. de Fisica i Enginyeria Nuclear, Univ. Pol. de Catalunya, E-08036 Barcelona, Spain

E-mail contact: raga *at* nucleares.unam.mx

Models of accretion disks around a star in a binary system predict that the disk will have a retrograde precession with a period a factor of ~ 10 times the orbital period. If the star+disk system ejects a bipolar outflow, this outflow will be subject to the effects of both the orbital motion and the precession. We present an analytic, ballistic model and a 3D gasdynamical simulation of a bipolar outflow from a source in a circular orbit, and with a precessing outflow axis. We find that this combination results in a jet/counterjet system with a small spatial scale, reflection-symmetric spiral (resulting from the orbital motion) and a larger scale, point-symmetric spiral (resulting from the longer period precession). These results provide interesting possibilities for modelling specific Herbig-Haro jets and bipolar planetary nebulae.

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The Taurus Spitzer Survey: New Candidate Taurus Members Selected Using Sensitive Mid-Infrared Photometry

L. M. Rebull[1], D. L. Padgett[1], C.-E. McCabe[1], L. A. Hillenbrand[2], K. R. Stapelfeldt[3], A. Noriega-Crespo[1], S. J. Carey[1], T. Brooke[1], T. Huard[4], S. Terebey[5], M. Audard[6,7], J.-L. Monin[8], M. Fukagawa[9], M. Güdel[10], G. R. Knapp[11], F. Menard[8], L. E. Allen[12], J. R. Angione[3,5], C. Baldovin-Saavedra[6,7], J. Bouvier[8], K. Briggs[10], C. Dougados[8], N. J. Evans[13], N. Flagey[1], S. Guieu[1], N. Grosso[14], A. M. Glauser[10,15], P. Harvey[13], D. Hines[16], W. B. Latter[17], S. L. Skinner[18], S. Strom[12], J. Tromp[5], and S. Wolf[19]

[1] Spitzer Science Center/Caltech, M/S 220-6, 1200 E. California Blvd., Pasadena, CA 91125

[2] Department of Astronomy, California Institute of Technology

[3] Jet Propulsion Laboratory

[4] University of Maryland, College Park

[5] California State University, Los Angeles

[6] ISDC Data Center for Astrophysics, University of Geneva, Ch. d'Ecogia 16, CH-1290 Versoix, Switzerland

[7] Observatoire de Genève, University of Geneva, Ch. des Maillettes 51, 1290 Versoix, Switzerland

[8] Laboratoire d'Astrophysique de Grenoble, Université de Grenoble – CNRS, UMR 5571, Grenoble, France

[9] Department of Earth and Space Science, Graduate School of Science, Osaka University, 1-1 Machikaneyama, Toyonaka, Osaka 560-0043 Japan Nagoya University, Japan

[10] ETH Zurich, Institute of Astronomy, 8093 Zurich, Switzerland

[11] Princeton University

[12] NOAO, Tucson, AZ

[13] University of Texas, Austin

[14] Observatoire astronomique de Strasbourg, Université de Strasbourg, CNRS, INSU, 11 rue de l'Université, 67000 Strasbourg, France
[15] UK Astronomy Technology Centre, Royal Observatory, Edinburgh EH9 3HJ, UK
[16] Space Science Institute
[17] NASA Herschel Science Center, IPAC, Pasadena, CA 91125
[18] CASA, University of Colorado, Boulder, CO 80309-0389
[19] University of Kiel, Institute of Theoretical Physics and Astrophysics, Leibnizstrasse 15, 24098 Kiel, Germany

E-mail contact: rebull *at* ipac.caltech.edu

We report on the properties of pre-main-sequence objects in the Taurus molecular clouds as observed in 7 mid- and far-infrared bands with the Spitzer Space Telescope. There are 215 previously-identified members of the Taurus star-forming region in our ∼44 square degree map; these members exhibit a range of Spitzer colors that we take to define young stars still surrounded by circumstellar dust (noting that ∼20% of the bonafide Taurus members exhibit no detectable dust excesses). We looked for new objects in the survey field with similar Spitzer properties, aided by extensive optical, X-ray, and ultraviolet imaging, and found 148 candidate new members of Taurus. We have obtained follow-up spectroscopy for about half the candidate sample, thus far confirming 34 new members, 3 probable new members, and 10 possible new members, an increase of 15-20% in Taurus members. Of the objects for which we have spectroscopy, 7 are now confirmed extragalactic objects, and one is a background Be star. The remaining 93 candidate objects await additional analysis and/or data to be confirmed or rejected as Taurus members. Most of the new members are Class II M stars and are located along the same cloud filaments as the previously-identified Taurus members. Among non-members with Spitzer colors similar to young, dusty stars are evolved Be stars, planetary nebulae, carbon stars, galaxies, and AGN.

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Preprints available linked from here: http://web.ipac.caltech.edu/staff/rebull/research.html

The Orbital Decay of Embedded Binary Stars

Steven W. Stahler[1]

[1] Berkeley Astronomy Dept, Berkeley, CA 94720

E-mail contact: SStahler *at* astro.berkeley.edu

Young binaries within dense molecular clouds are subject to dynamical friction from ambient gas. Consequently, their orbits decay, with both the separation and period decreasing in time. A simple analytic expression is derived for this braking torque. The derivation utilizes the fact that each binary acts as a quadrupolar source of acoustic waves. The acoustic disturbance has the morphology of a two-armed spiral and carries off angular momentum. From the expression for the braking torque, the binary orbital evolution is also determined analytically. This type of merger may help explain the origin of high-mass stars. If infrared dark clouds, with peak densities up to 10^7 cm^{-3}, contain low-mass binaries, those with separations less than 100 AU merge within about 10^5 yr. During the last few thousand years of the process, the rate of mechanical energy deposition in the gas exceeds the stars' radiative luminosity. Successive mergers may lead to the massive star formation believed to occur in these clouds.

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Spitzer and HHT observations of starless cores: masses and environments

A. Stutz[1,2]**, G. Rieke**[2]**, J. Bieging**[2]**, Z. Balog**[1]**, F. Heitch**[3]**, M. Kang**[2,4,5]**, W. Peters**[2]**, Y. Shirley**[2] **and M. Werner**[6]

[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany
[2] Steward Observatory, University of Arizona
[3] Dept. of Physics & Astronomy, University of North Carolina at Chapel Hill
[4] Korea Astronomy and Space Science Institute
[5] Department of Astronomy and Space Science, Chungnam National University, South Korea
[6] Jet Propulsion Lab, California Institute of Technology

E-mail contact: stutz *at* mpia.de

We present *Spitzer* observations of a sample of 12 starless cores selected to have prominent 24 μm shadows. The *Spitzer* images show 8 and 24 μm shadows and in some cases 70 μm shadows; these spatially resolved absorption features trace the densest regions of the cores. We have carried out a ^{12}CO (2-1) and ^{13}CO (2-1) mapping survey of these cores with the Heinrich Hertz Telescope (HHT). We use the shadow features to derive optical depth maps. We derive molecular masses for the cores and the surrounding environment; we find that the 24 μm shadow masses are always greater than or equal to the molecular masses derived in the same region, a discrepancy likely caused by CO freeze–out onto dust grains. We combine this sample with two additional cores that we studied previously to bring the total sample to 14 cores. Using a simple Jeans mass criterion we find that $\sim 2/3$ of the cores selected to have prominent 24 μm shadows are collapsing or near collapse, a result that is supported by millimeter line observations. Of this subset at least half have indications of 70 μm shadows. All cores observed to produce absorption features at 70 μm are close to collapse. We conclude that 24 μm shadows, and even more so the 70 μm ones, are useful markers of cloud cores that are approaching collapse.

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Dust Transport in Protostellar Disks Through Turbulence and Settling

N. J. Turner[1], A. Carballido[1,2] and T. Sano[3]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109, USA
[2] Instituto de Astronomía, Universidad Nacional Autónoma de México, DF 04510, México
[3] Institute of Laser Engineering, Osaka University, Suita, Osaka 565-0871, Japan

E-mail contact: neal.turner *at* jpl.nasa.gov

We apply ionization balance and MHD calculations to investigate whether magnetic activity moderated by recombination on dust grains can account for the mass accretion rates and the mid-infrared spectra and variability of protostellar disks. The MHD calculations use the stratified shearing-box approach and include grain settling and the feedback from the changing dust abundance on the resistivity of the gas. The two-decade spread in accretion rates among Solar-mass T Tauri stars is too large to result solely from variations in the grain size and stellar X-ray luminosity, but can plausibly be produced by varying these parameters together with the disk magnetic flux. The diverse shapes and strengths of the mid-infrared silicate bands can come from the coupling of grain settling to the distribution of the magneto-rotational turbulence, through the following three effects. First, recombination on grains 1 μm or smaller yields a magnetically-inactive dead zone extending more than two scale heights from the midplane, while turbulent motions in the magnetically-active disk atmosphere overshoot the dead zone boundary by only about one scale height. Second, grains deep in the dead zone oscillate vertically in wave motions driven by the turbulent layer above, but on average settle at the rates found in laminar flow, so that the interior of the dead zone is a particle sink and the disk atmosphere will become dust-depleted unless resupplied from elsewhere. Third, with sufficient depletion, the dead zone is thinner and mixing dredges grains off the midplane. The last of these processes enables evolutionary signatures such as the degree of settling to sometimes decrease with age. The MHD results also show that the magnetic activity intermittently lifts clouds of small grains into the atmosphere. Consequently the photosphere height changes by up to one-third over timescales of a few orbits, while the extinction along lines of sight grazing the disk surface varies by factors of two over times down to a tenth of an orbit. We suggest that the changing shadows cast by the dust clouds on the outer disk are a cause of the daily to monthly mid-infrared variability found in some young stars.

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An HST View of the Interstellar Environments of Young Stellar Objects in the Large Magellanic Cloud

Kaushar Vaidya[1], You-Hua Chu[1], Robert Gruendl[1], C.-H. Rosie Chen[2] and Leslie Looney[1]

[1] University of Illinois at Urbana-Champaign, USA
[2] University of Virginia, USA

E-mail contact: kausharr *at* gmail.com

We have used archival HST Hα images to study the immediate environments of massive and intermediate-mass young stellar object (YSO) candidates in the Large Magellanic Cloud (LMC). The sample of YSO candidates, taken from Gruendl & Chu (2009), was selected based on Spitzer IRAC and MIPS observations of the entire LMC and complementary ground-based optical and near-infrared observations. We found HST Hα images for 99 YSO candidates in the LMC, of which 82 appear to be genuine YSOs. More than 95% of the YSOs are found to be associated with molecular clouds. YSOs are seen in three different kinds of environments in the Hα images: in dark clouds, inside or on the tip of bright-rimmed dust pillars, and in small H II regions. Comparisons of spectral energy distributions for YSOs in these three different kinds of environments suggest that YSOs in dark clouds are the youngest, YSOs with small H II regions are the most evolved, and YSOs in bright-rimmed dust pillars span a range of intermediate evolutionary stages. This rough evolutionary sequence is substantiated by the presence of silicate absorption features in the Spitzer IRS spectra of some YSOs in dark clouds and in bright-rimmed dust pillars, but not those of YSOs in small H II regions. We present a discussion on triggered star formation for YSOs in bright-rimmed dust pillars or in dark clouds adjacent to H II regions. As many as 50% of the YSOs are resolved into multiple sources in high-resolution HST images. This illustrates the importance of using high-resolution images to probe the true nature and physical properties of YSOs in the LMC.

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High- and Low-Mass Star Forming Regions from Hierarchical Gravitational Fragmentation. High local Star Formation Rates with Low Global Efficiencies

Enrique Vázquez-Semadeni[1], Gilberto C. Gómez[1], A.-Katharina Jappsen[2], Javier Ballesteros-Paredes[1] and Ralf S. Klessen[3]

[1] Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Apdo. Postal 3-72, Morelia, Michoacán, 58089, México

[2] School of Physics & Astronomy, Cardiff University, Queens Buildings, The Parade, Cardiff CF24 3AA, UK

[3] Zentrum für Astronomie der Universität Heidelberg, Institut für Theoretische Astrophysik, 69120 Heidelberg, Germany

E-mail contact: e.vazquez *at* crya.unam.mx

We investigate the properties of "star forming regions" in a previously published numerical simulation of molecular cloud formation out of compressive motions in the warm neutral atomic interstellar medium, neglecting magnetic fields and stellar feedback. We study the properties (density, total gas+stars mass, stellar mass, velocity dispersion, and star formation rate) of the cloud hosting the first local, isolated "star formation" event and compare them with those of the cloud formed by the central, global collapse event. In this simulation, the velocity dispersions at all scales are caused primarily by infall motions rather than by random turbulence. We suggest that the small-scale isolated collapses may be representative of low- to intermediate-mass star-forming regions, with gas masses ($M_{\rm gas}$) of hundreds of solar masses, velocity dispersions $\sigma_v \sim 0.7$km s^{-1}, and star formation rates (SFRs) $\sim 3 \times 10^{-5} M_\odot {\rm yr}^{-1}$, while the large-scale, massive ones may be representative of massive star forming regions, with $M_{\rm gas}$ of thousands of solar masses, $\sigma_v \sim$ a few km s^{-1}, and SFRs $\sim 3\times10^{-4} M_\odot {\rm yr}^{-1}$. We also compare the statistical distributions of the physical properties of the dense cores appearing in the central region of massive collapse with those from a recent survey of the massive star forming region in the Cygnus X molecular cloud, finding that the observed and simulated distributions are in general very similar.

However, we find that the star formation efficiency per free-fall time (SFE$_{\rm ff}$) of the high mass region, similarly to that of OMC-1, is low, ~ 0.04. In the simulated cloud, this is *not* a consequence of a "slow" SFR in a nearly hydrostatic cloud supported by turbulence, but rather of the region accreting mass at a high rate. Thus, we find that measuring a low SFE$_{\rm ff}$ may be incorrectly interpreted as implying a lifetime much longer than the core's local free-fall time, and an SFR much slower than that given by the free-fall rate, if the accretion is not accounted for. We suggest that, rather than requiring a low value of the SFE$_{\rm ff}$ everywhere in the Galaxy, attaining a globally low specific SFR requires star formation to be a spatially intermittent process, so that most of the mass in a GMC is not participating of the SF process at any given time. Locally, the specific SFR of a star-forming region can be much larger than the global GMC's average.

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The clumpiness of molecular clouds: HCO^+ (3–2) survey near Herbig-Haro objects

W. Whyatt[1], J.M. Girart[2], S. Viti[1], R. Estalella[3] and D.A. Williams[1]

[1] Department of Physics & Astronomy, University College London
[2] Institut de Ciències de l'Espai (CSIC-IEEC),
[3] Departament d'Astronomia i Meteorologia, Universitat de Barcelona

E-mail contact: sv *at* star.ucl.ac.uk

Some well-studied Herbig Haro objects have associated with them one or more cold, dense, and quiescent clumps of gas. We propose that such clumps near an HH object can be used as a general measure of clumpiness in the molecular cloud that contains that HH object. Our aim is to make a survey of clumps around a sample of HH objects, and to use the results to make an estimate of the clumpiness in molecular clouds. All known cold, dense, and quiescent clumps near HH objects are anomalously strong HCO^+ emitters. Our method is, therefore, to search for strong HCO^+ emission as an indicator of a clump near to an HH object. The searches were made using JCMT (for Northern hemisphere objects) and SEST (for Southern hemisphere objects) in the HCO^+ (3–2) and also (for SEST observations) $H^{13}CO^+$ (1–0) lines, with some additional searches for methanol and sulphur monoxide lines. The sources selected were a sample of 22 HH objects in which no previous HCO^+ emission had been detected. We find that half of the HH objects have clumps detected in the HCO^+ (3–2) line and that all searches in $H^{13}CO^+$ 1-0 lines show evidence of clumpiness. All condensations have narrow linewidths and are evidently unaffected dynamically by the HH jet shock. We conclude that the molecular clouds in which these HH objects are found must be highly heterogeneous on scales of less than 0.1 pc. An approximate calculation based on these results suggests that the area filling factor of clumps affected by HH objects is on the order of 10%. These clumps have gas number densities of $\gtrsim 3 \times 10^4$ cm^{-2}.

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Planetesimal and Protoplanet Dynamics in a Turbulent Protoplanetary Disk: Ideal Unstratified Disks

Chao-Chin Yang[1,2], Mordecai-Mark Mac Low[2] and Kristen Menou[3]

[1] University of Illinois, Urbana, IL 61801, USA
[2] American Museum of Natural History, New York, NY 10024, USA
[3] Columbia University, New York, NY 10027, USA

E-mail contact: cyang *at* amnh.org

The dynamics of planetesimals and planetary cores may be strongly influenced by density perturbations driven by magneto-rotational turbulence in their natal protoplanetary gas disks. Using the local shearing box approximation, we perform numerical simulations of planetesimals moving as massless particles in a turbulent, magnetized, unstratified gas disk. Our fiducial disk model shows turbulent accretion characterized by a Shakura-Sunyaev viscosity parameter of $\alpha \sim 10^{-2}$, with root-mean-square density perturbations of $\sim$10%. We measure the statistical evolution of particle orbital properties in our simulations including mean radius, eccentricity, and velocity dispersion. We confirm random walk growth in time of all three properties, the first time that this has been done with direct orbital integration in a local model. We find that the growth rate increases with the box size used at least up to boxes of eight scale heights in horizontal size. However, even our largest boxes show velocity dispersions sufficiently low that collisional destruction of planetesimals should be unimportant in the inner disk throughout its lifetime. Our direct integrations agree with earlier torque measurements showing that type I migration dominates over diffusive migration by stochastic torques for most objects in the planetary core and terrestrial planet mass range. Diffusive migration remains important for objects in the mass range of kilometer-sized planetesimals. Discrepancies in the derived magnitude of turbulence between local and global simulations of magneto-rotationally unstable disks remains an open issue, with important consequences for planet formation scenarios.

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A contracting circumbinary molecular ring with an inner cavity of about 140 AU around Ori 139-409

Luis A. Zapata[1], Peter Schilke[1,2], and Paul T. P. Ho[3,4]

[1]Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121, Bonn, Germany
[2]Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany
[3]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[4]Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan

E-mail contact: lzapata *at* mpifr-bonn.mpg.de

Sensitive and subarcsecond resolution ($\sim 0.7''$) $CH_3OH(7_{-2,6} \rightarrow 6_{-2,5})$ line and 890 μm continuum observations made with the Submillimeter Array (SMA) towards the hot molecular circumbinary ring associated with the young multiple star *Ori 139-409* are presented. The $CH_3OH(7_{-2,6}$ - $6_{-2,5})$ emission from the ring is well resolved at this angular resolution revealing an inner cavity with a size of about 140 AU. A LTE model of a Keplerian disk with an inner cavity of the same size confirms the presence of this cavity. Additionally, this model suggests that the circumbinary ring is contracting with a velocity of $V_{inf} \sim 1.5$ km s^{-1} toward the binary central compact circumstellar disks reported at a wavelength of 7 mm. The inner central cavity seems to be formed by the tidal effects of the young stars in the middle of the ring. The ring appears to be not a stationary object. Furthermore, the infall velocity we determine is about a factor of 3 slower than the free-fall velocity corresponding to the dynamical mass. This would correspond to a mass accretion rate of about 10^{-5} $M_\odot$/yr. We found that the dust emission associated with Ori 139-409 appears to be arising from the circumstellar disks with no strong contribution from the molecular gas ring. A simple comparison with other classical molecular dusty rings (*e.g.* GG Tau, UZ Tau, and UY Aur) suggests that *Ori 139-409* could be one of the youngest circumbinary rings reported up to date. Finally, our results confirm that the circumbinary rings are actively funneling fresh gas material to the central compact binary circumstellar disks, *i.e.* to the protostars in the very early phases of their evolution.

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

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The Star Formation Newsletter is available on the World Wide Web at http://www.ifa.hawaii.edu/users/reipurth/newsletter.htm.

Dust Processing and Mineralogy in Protoplanetary Accretion Disks

Thomas Henning[1] and Gwendolyn Meeus[2,3]

[1] MPIA, Königstuhl 17, D-69117 Heidelberg, Germany
[2] AIP, An der Sternwarte 16, D-14482 Potsdam, Germany
[3] Universidad Autonoma de Madrid, Cantoblanco, Madrid, Spain

E-mail contact: henning *at* mpia-hd.mpg.de

We discuss the different dust components of a protoplanetary disk with a special emphasis on grain composition, size and structure. The paper will highlight the role dust grains play in protoplanetary disks, as well as observational results supporting this knowledge. First, the path dust travels from the interstellar medium into the CS disk is described. Then dust condensation sequences from the gas are introduced, to determine the most likely species that occur in a disk. The characteristics of silicates are handled in detail: composition, lattice structure, magnesium to iron ratio and spectral features. The other main dust-forming component of the interstellar medium, carbon, is presented in its many forms, from molecules to more complex grains. Observational evidence for PAHs is given for both young stars and solar system material. We show how light scattering theory and laboratory data can be used to provide the optical properties of dust grains. From the observer's point of view, we discuss how infrared spectra can be used to derive dust properties, and present the main spectral analysis methods currently used and their limitations. Observational results, determining the dust properties in protoplanetary disks, are given: first for the bright intermediate-mass Herbig Ae/Be stars, and then for the lower-mass Tauri stars and brown dwarfs. Here we present results from the space observatories ISO and Spitzer, as well as from the mid-infrared interferometer VLTI, and summarise the main findings. We discuss observational evidence for grain growth in both Herbig Ae/Be and T Tauri stars, and its relation with spectral type and dust settling. We conclude with an outlook on future space missions that will open new windows, towards longer wavelengths and even fainter objects.

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http://arxiv.org/abs/0911.1010

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Peering into the Heart of Galactic Star Formation: A Detailed Characterization of Infrared-Dark Clouds

Sarah Ragan

University of Michigan, USA

830 Dennison Building, 500 Church Street, Ann Arbor, MI, 48109, USA

Address as of 5 Jan 2010: Max Planck Institute for Astronomy, Königstuhl 17, D-69117, Heidelberg, DE

Electronic mail: seragan *at* umich.edu

Ph.D dissertation directed by: Ted Bergin

Ph.D degree awarded: October 2009

Everything we know about other galaxies is based on light from massive stars, yet, in our own Galaxy, it's the formation of massive stars that is the least understood. Star formation studies to date have focused on nearby, low-mass regions, but the bulk of star formation takes place in massive clusters, which takes place primarily in the inner-Galaxy, where the bulk of the molecular gas resides. To learn about the conditions under which massive clusters form, we seek out their precursors, called infrared-dark clouds (IRDCs).

We present the results of a high-resolution multi-wavelength observational study of IRDCs, which vastly improves our knowledge of the initial conditions of cluster formation. Beginning with IRDC candidates identified with Midcourse Science Experiment (MSX) survey data, we map 41 IRDCs in the N_2H^+ $1 \rightarrow 0$, CS $2 \rightarrow 1$ and $C^{18}O$ $1 \rightarrow 0$ molecular transitions using the Five College Radio Astronomy Observatory. We examine the stellar content and absorption structure with *Spitzer Space Telescope* observations of eleven IRDCs, and we use Very Large Array NH_3 observations to probe the kinematics and chemistry of six IRDCs.

Our comprehensive high-resolution study of IRDCs confirms that these objects are cold and dense precursors to massive stars and clusters. For the first time, we quantify IRDC sub-structure on sub-parsec scales and show the kinematic structure of IRDCs is diverse and depends on associated local star-formation activity. Overall, IRDCs exhibit non-thermal dynamics, suggesting that turbulence and systematic motions dominate. IRDC temperatures are between 8 and 16 K and are mostly flat with hints of a rise near the edges due to external heating. This study shows that IRDCs are a unique star-forming environment, one that dominates the star formation in the Milky Way.

Using high-resolution observations, we have quantified the structure, star formation, kinematics, and chemistry of infrared-dark clouds. Our study of sub-structure in particular shows that IRDCs are undergoing fragmentation and are the precursors to star clusters, and thus we have placed IRDCs in context with Galactic star formation. The characterization presented here offers new constraints on theories of molecular cloud fragmentation and clustered star formation.

http://www.astro.lsa.umich.edu/~seragan/ftp/thesis/

Spitzer and HHT observations of the earliest stages of star formation

Amelia Stutz

Steward Observatory, University of Arizona, USA

Address as of 10 Aug 2009: Max Planck Institute for Astronomy, Königstuhl 17, D-69117, Heidelberg, Germany

Electronic mail: stutz *at* mpia.de

Ph.D dissertation directed by: George H. Rieke & John H. Bieging

Ph.D degree awarded: June 2009

We use *Spitzer Space Telescope* and Heinrich Hertz Telescope (HHT) observations to study the earliest stages of low–mass star formation. Using spatially resolved absorption features, termed shadows, we study the cold cloud cores where stars form.

We study Barnard 335, a prototypical isolated Bok globule with an embedded Class 0 protostar. We discover an 8 μm shadow in the inner regions of the core; using this feature we measure the dense core structure and mass. Using HHT observations we detect a rotating structure, a flattened molecular core, with a diameter $\sim 10,000$ AU. The flattened molecular core is likely to be the same structure as that generating the 8 μm shadow, and is expected from theoretical simulations. This structure has not been robustly detected in previous observations although there have been some prior indications of its presence.

We study dense starless core structure through longer wavelength observations of shadows; we present *Spitzer* observations of 8 μm, 24 μm, and 70 μm shadows of 14 cores in total. Combined with HHT observations of ^{12}CO 2–1 and ^{13}CO 2–1, we derive core sizes, masses, study core structure, and investigate the collapse status of each core. Our study of starless core CB190 reveals that the core is likely to be stable against collapse if magnetic pressure is present at a reasonable level in the core. Our study of the 70 μm shadow associated with the starless core L429 reveals that this object is very likely to be collapsing. Finally, we study a sample of 12 starless cores selected to have prominent 24 μm shadows. We find that about 2/3 of these sources are likely to be collapsing. Additionally, we find indications that 1/2 of the cores revealed to be collapse candiates show indications of having 70 μm shadows. We conclude that all cores dense enough to produce 70 μm shadows are collapse candidates, and that the presence of a shadow at 24 μm is an indicator that the core is likely ($\gtrsim$60% probability) to be collapsing.

Post-Doctoral Fellowship – Star Formation in Nearby Galaxies Arcetri Astrophysical Observatory

The INAF – Arcetri Astrophysical Observatory (Florence) intends to award a post-doctoral fellowship in the field of Extragalactic Star Formation. The fellow is expected to focus his/her activity on the properties of young star forming regions in nearby galaxies: from the time newly born stars are embedded in the parent molecular cloud to the stage in which massive stars evole off the main sequence.

The goals will be to establish: (i) possible evidence for a time sequence and/or variations in populating the IMF; (ii) the dependence of young cluster properties on local conditions and on host galaxy characteristics; (iii) consequences of the above on SFR tracers and on synthesis models from small scales to the galaxy as a whole. As such, some experience in photometric methods and synthesis models for multiwavelgth datasets is desirable. Successful candidate will work in collaboration with F.Palla, E. Corbelli, C.Giovanardi and will benefit in general of the interaction with the large star formation group in Arcetri.

Applicants must have a Ph.D. or equivalent at the starting date of the fellowship. The gross yearly salary will be 30,000 Euro, and will not entail social benefits or medical insurance. The fellowship will be granted for one year; extension for a second year will be conditional on a positive evaluation of the research activity carried out during the first year. No special application forms are required. The applicants should send a CV and a list of publications to the above submission address and should arrange for two letters of recommendation to be sent separately to the same address. E-mail submission is accepted.

Applications should arrive in Arcetri no later than December 23, 2009. The starting date is negotiable but in any case within the spring 2010.

PhD position Water in Star-forming Regions at Leiden Observatory

A 4-year PhD position is available to study the physical and chemical evolution of star-forming regions using data on water and related molecules to be obtained in the context of two approved Herschel key programs, WISH and DIGIT. Complementary ground-based submillimeter programs using JCMT, APEX and submillimeter interferometers are planned as well. The analysis will involve state-of-the-art radiative transfer techniques and chemical-dynamical models. The aim is to study the evolution of water and related molecules from the coldest pre-stellar cores to their incorporation into protoplanetary disks, and from low- to high-mass young stellar objects.

Applications should be submitted through the general Leiden Observatory application form at

www.strw.leidenuniv.nl/phd/apply.php.

by December 15 2009. The positions are open to students of all nationalities with the equivalent of a "doctoraal" (Masters) degree in astronomy, physics or chemistry. The starting date for the position can be anytime in 2010. See: www.strw.leidenuniv.nl/∼ewine and www.strw.leidenuniv.nl/WISH/ for more information.

Postdoctoral position in star- and planet formation

A 2-year postdoc position is available at the Max-Planck Institut fur Extraterrestrische Physik in Garching to work on observational or theoretical studies of star- and planet formation. The postdoc will be able to pursue a personal research program in this area and is also expected to be part of a larger team studying the physical and chemical evolution of young stellar objects and protoplanetary disks using Spitzer and Herschel (in the context of the WISH and DIGIT key programs) spectroscopy as well as ground-based infrared and submillimeter surveys.

Applications should include a curriculum vitae, publication list, and a brief statement of research experience and interests, and arrange for at least three letters of reference to be sent to ewine *at* strw.leidenuniv.nl by January 10 2010. See www.mpe.mpg.de/ir/ir_research.php?lang=en and www.strw.leidenuniv.nl/WISH/ for information.

Meetings

Magnetic Fields
From Core Collapse to Young Stellar Objects
May 17th to 19th 2010
The University of Western Ontario London, Ontario, Canada

The transformation of a dragged-in interstellar magnetic field into a (fossil or dynamo-generated) stellar field, and the associated magnetic flux problem, is a fundamental process in astrophysics. Recent progress in MHD simulations of core collapse reveal a revitalized role for magnetic braking in the late collapse stages. Magnetic fields are crucial in determining the angular momentum content (or even the existence) of circumstellar disks as well as in outflow generation and star-disk interactions. The magnetic flux problem, and its resolution by non-ideal MHD processes, is then intimately related to the angular momentum problem and the origin of stellar masses. In addition, recent spectropolarimetric studies of magnetic fields in Herbig AeBe stars reveal that a re-examination of the standard magnetospheric accretion paradigm may be in order. High-resolution polarimetry is also revealing the magnetic field morphology with net poloidal flux and an hourglass shape within the inner collapse zone. This conference will emphasize the emerging results in magnetic field simulations, observations, and theory as it applies to the late phase of collapse and early YSO evolution.

Scientific Organizing Committee:
Evelyne Alecian (France), Shantanu Basu (Canada, Chair), Moria Jardine (UK), Takahiro Kudoh (Japan), John Landstreet (Canada), Zhi-Yun Li (USA), Ramprasad Rao (Taiwan/USA), Kostas Tassis (USA), Mark Wardle (Australia)

Local Organizing Committee:
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