THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 206 — 21 Feb 2010 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

Abstracts of recently accepted papers

Collision between dissimilar clouds : Stability of the bow shock, and the formation of prestellar cores

Sumedh Anathpindika[1]

[1] Indian Institute of Astrophysics, Bangalore 560034, India

E-mail contact: sumedh.anathpindika *at* astro.cf.ac.uk

We use smoothed particle hydrodynamics to simulate a head-on collision between two physically dissimilar clouds, and investigate the dynamical stability of the post-collision bow-shock. The shock-front appears susceptible to a number of hydrodynamical instabilities such as the Kelvin-Helmholtz instability, the Rayleigh-Taylor instability, and the Thin shell instability (TSI). We initially perform three realisations of the simulation by progressively increasing the number of SPH particles, and therefore the resolution. It is observed that lack of sufficient resolution tends to damp the growth of perturbations on the shock-front which in turn suppresses fragmentation. Thus poorer resolution favours formation of contiguous structure while the fingers, characteristic of the Rayleigh-Taylor instability, hardly appear. However, the gross physical features seem independent of resolution, the bow-shock in each of the three cases becomes unstable to the TSI which once triggered, grows rapidly and eventually becomes non-linear. Albeit, the TSI appears to grow at a rate much slower than that predicted analytically. The TSI contributes to dissipation of gas kinetic energy within the curved shock-front via internal shocking, eventually the bow-shock collapses to form a filament oriented along the collision axis; prestellar cores form in this filament. The wings of the bow-shock are also unstable to the TSI and consequently appear filamentary with a few clumps, which rapidly disrupt over a period of a few times 10^5 years. Formation of such transitional clumps may explain the occurrence of starless cores often found in filamentary regions. Having commenced with perfectly stable initial conditions, the reported instabilities in the bow-shock originate purely through numerical noise. Turbulence within the shock-front, however, appears to locally suppress the gravitational instability. We demonstrate that a global gravitational contraction can produce turbulence, large enough to contain prestellar cores. Finally, we also discuss a case in which the initial density contrast between the precollision clouds was further increased by an order of magnitude, while colliding them at a much lower velocity.

Accepted by MNRAS

Sequential Star Formation in RCW 34: A Spectroscopic Census of the Stellar Content of High-mass Star-forming Regions

A. Bik[1], E. Puga[2,3], L.B.F.M. Waters[3,4], M. Horrobin[4,5], Th. Henning[1], T. Vasyunina[1], H. Beuther[1], H. Linz[1], L. Kaper[4], M. van den Ancker[6], A. Lenorzer[7], E. Churchwell[8], S. Kurtz[9], M.B.N. Kouwenhoven[10,11], A. Stolte[5], A. de Koter[4,12], W-. F. Thi[13], F. Comeron[6] and Ch. Waelkens[3]

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

[2] Centro de Astrobiología (CSIC-INTA), 28850 Torrejón de Ardoz, Madrid, Spain

[3] Instituut voor Sterrenkunde, Celestijnenlaan 200D, B-3001 Leuven, Belgium

[4] Sterrenkundig Instituut "Anton Pannekoek", University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

[5] I.Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany

[6] European Southern Observatory, Karl-Schwarzschild Strasse 2, Garching-bei-München, D-85748, Germany

[7] Instituto Astrofísica de Canarias, Vía Láctea s/n, E-38200 La Laguna, Spain
[8] University of Wisconsin, 475 North Charter Street, WI53706 Madison, USA
[9] CRyA, Universidad Nacional Autónoma de México, Apdo. 3-72, 58090 Morelia, Michoacán, México
[10] The Kavli Institute for Astronomy and Astrophysics, Peking University, Yi He Yuan Lu 5, Hai Dian Qu, Beijing 100871, China
[11] University of Sheffield, Hicks Building, Hounsfixeld Road, Sheffield S3 7RH, United Kingdom
[12] Astronomical Institute, Utrecht University, Princetonplein 5, 3584CC Utrecht, The Netherlands
[13] SUPA, Institute for Astronomy, University of Edinburgh, Royal Observatory Edinburgh, Backford Hill, Edinburgh, EH9 3HJ, United Kingdom

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

In this paper we present VLT/SINFONI integral field spectroscopy of RCW 34 along with *Spitzer*/IRAC photometry of the surroundings. RCW 34 consists of three different regions. A large bubble has been detected on the IRAC images in which a cluster of intermediate- and low-mass class II objects is found. At the northern edge of this bubble, an H II region is located, ionized by 3 OB stars, of which the most massive star has spectral type O8.5V. Intermediate mass stars (2 - 3 $M_\odot$) are detected of G- and K- spectral type. These stars are still in the pre-main sequence (PMS) phase. North of the H II region, a photon-dominated region is present, marking the edge of a dense molecular cloud traced by H_2 emission. Several class 0/I objects are associated with this cloud, indicating that star formation is still taking place.

The distance to RCW 34 is revised to 2.5 $\pm$ 0.2 kpc and an age estimate of 2 $\pm$ 1 Myrs is derived from the properties of the PMS stars inside the H II region. Between the class II sources in the bubble and the PMS stars in the H II region, no age difference could be detected with the present data. The presence of class 0/I sources in the molecular cloud, however, suggests that the objects inside the molecular cloud are significantly younger.

The most likely scenario for the formation of the three regions is that star formation propagates from South to North. First the bubble is formed, produced by intermediate- and low-mass stars only, after that, the H II region is formed from a dense core at the edge of the molecular cloud, resulting in the expansion as a champagne flow. More recently, star formation occurred in the rest of the molecular cloud. Two different formation scenarios are possible: (a) The bubble with the cluster of low- and intermediate mass stars triggered the formation of the O star at the edge of the molecular cloud which in turn induces the current star-formation in the molecular cloud. (b) An external triggering is responsible for the star-formation propagating from South to North.

Accepted by ApJ

http://arxiv.org/abs/1002.2571

Detection of $N^{15}NH^+$ in L1544

L. Bizzocchi[1], P. Caselli[2] and L. Dore[3]

[1] CAAUL, Observatório Astronómico de Lisboa, Tapada da Ajuda, 1349-018, Lisboa, Portugal
[2] School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK
[3] Dipartimento di Chimica “G. Ciamician”, Università di Bologna, via F. Selmi 2, I-40126 Bologna, Italy

E-mail contact: bizzocchi *at* oal.ul.pt

Excess levels of ^{15}N isotopes which have been detected in primitive solar system materials are explained as a remnant of interstellar chemistry which took place in regions of the protosolar nebula. Chemical models of nitrogen fractionation in cold clouds predict an enhancement in the gas-phase abundance of ^{15}N-bearing molecules, thus we have searched for ^{15}N variants of the N_2H^+ ion in L1544, which is one of the best candidate sources for detection owing to its low central core temperature and high CO depletion. With the IRAM 30 m telescope we have obtained deep integrations of the $N^{15}NH^+$ $(1-0)$ line at 91.2 GHz. The $N^{15}NH^+$ $(1-0)$ line has been detected toward the dust emission peak of L1544. The $^{14}N/^{15}N$ abundance ratio in $N^{15}NH^+$ resulted 446 ± 71, very close to the protosolar value of ~ 450, higher than the terrestrial ratio of ~ 270, and significantly lower than the lower limit in L1544 found by Gerin et al. (2009, ApJ, 570, L101) in the same object using ammonia isotopologues.

Accepted by Astronomy & Astrophysics

http://de.arxiv.org/abs/1001.4903

The Density Variance – Mach Number Relation in the Taurus Molecular Cloud

Chris Brunt[1]

[1] School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

E-mail contact: brunt *at* astro.ex.ac.uk

Supersonic turbulence in molecular clouds is a key agent in generating density enhancements that may subsequently go on to form stars. The stronger the turbulence – the higher the Mach number – the more extreme the density fluctuations are expected to be. Numerical models predict an increase in density variance, σ^2_{ρ/ρ_0}, with rms Mach number, M of the form: $\sigma^2_{\rho/\rho_0} = b^2M^2$, where b is a numerically-estimated parameter, and this prediction forms the basis of a large number of analytic models of star formation. We provide an estimate of the parameter b from ^{13}CO J=1 -0 spectral line imaging observations and extinction mapping of the Taurus molecular cloud, using a recently developed technique that needs information contained solely in the projected column density field to calculate σ^2_{ρ/ρ_0}. When this is combined with a measurement of the rms Mach number, M, we are able to estimate b. We find $b = 0.48^{+0.15}_{-0.11}$, which is consistent with typical numerical estimates, and is characteristic of turbulent driving that includes a mixture of solenoidal and compressive modes. More conservatively, we constrain b to lie in the range 0.3–0.8, depending on the influence of sub-resolution structure and the role of diffuse atomic material in the column density budget (accounting for sub-resolution variance results in higher values of b, while inclusion of more low column density material results in lower values of b; the value $b = 0.48$ applies to material which is predominantly molecular, with no correction for sub-resolution variance). We also report a break in the Taurus column density power spectrum at a scale of ~ 1 pc, and find that the break is associated with anisotropy in the power spectrum. The break is observed in both ^{13}CO and dust extinction power spectra, which, remarkably, are effectively identical despite detailed spatial differences between the ^{13}CO and dust extinction maps.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/1002.1239

The Dynamical Evolution of the Pleiades

Joseph M. Converse[1] **and Steven W. Stahler**[1]

[1] Astronomy Dept., U. of California, Berkeley, CA 94720, USA

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

We present the results of a numerical simulation of the history and future development of the Pleiades. This study builds on our previous one that established statistically the present-day structure of this system. Our simulation begins just after molecular cloud gas has been expelled by the embedded stars. We then follow, using an N-body code, the stellar dynamical evolution of the cluster to the present and beyond. Our initial state is that which evolves, over the 125 Myr age of the cluster, to a configuration most closely matching the current one. We find that the original cluster, newly stripped of gas, already had a virial radius of 4 pc. This configuration was larger than most observed, embedded clusters. Over time, the cluster expanded further and the central surface density fell by about a factor of two. We attribute both effects to the liberation of energy from tightening binaries of short period. Indeed, the original binary fraction was close to unity. The ancient Pleiades also had significant mass segregation, which persists in the cluster today. In the future, the central density of the Pleiades will continue to fall. For the first few hundred Myr, the cluster as a whole will expand because of dynamical heating by binaries. The expansion process is aided by mass loss through stellar evolution, which weakens the system's gravitational binding. At later times, the Galactic tidal field begins to heavily deplete the cluster mass. It is believed that most open clusters are eventually destroyed by close passage of a giant molecular cloud. Barring that eventuality, the density falloff will continue for as long as 1 Gyr, by which time most of the cluster mass will have been tidally stripped away by the Galactic field.

Accepted by MNRAS

http://arxiv.org/abs/1002.2229

The JCMT Legacy Survey of the Gould Belt: a first look at Taurus with HARP

Chris J. Davis[1], Antonio Chrysotomou[1], Jenny Hatchell[2], Jan Wouterloot[1], Jane Buckle[3], Dave Nutter[4], Michel Fich[5], Chris Brunt[2] and the Gould Belt Survey team[6]

[1] Joint Astronomy Centre, 660 North A'ohōkū Place, University Park, Hilo, Hawaii 96720, USA
[2] School of Physics, University of Exeter, Stocker Road, Exeter, U.K.
[3] Cavendish Laboratory, Cambridge University, J.J. Thomson Avenue, Cambridge, CB3 9HE, U.K.
[4] School of Physics and Astronomy, Cardiff University, 5 The Parade, Cardiff, U.K.
[5] Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada.
[6] Various

E-mail contact: c.davis *at* jach.hawaii.edu

As part of a JCMT Legacy Survey of star formation in the Gould Belt, we present early science results for Taurus. CO J=3-2 maps have been secured along the north-west ridge and bowl, collectively known as L 1495, along with deep ^{13}CO and C^{18}O J=3-2 maps in two sub-regions. With these data we search for molecular outflows, and use the distribution of flows, HH objects and shocked H_2 line emission features, together with the population of young stars, protostellar cores and starless condensations to map star formation across this extensive region. In total 21 outflows are identified. It is clear that the bowl is more evolved than the ridge, harbouring a greater population of T Tauri stars and a more diffuse, more turbulent ambient medium. By comparison, the ridge contains a much younger, less widely distributed population of protostars which, in turn, is associated with a greater number of molecular outflows. We estimate the ratio of the numbers of prestellar to protostellar cores in L 1495 to be $\sim$1.3–2.3, and of gravitationally unbound starless cores to (gravitationally bound) prestellar cores to be $\sim$1. If we take previous estimates of the protostellar lifetime of $\sim 5\times10^5$ yrs, this indicates a prestellar lifetime of $9(\pm3)\times10^5$ yrs. From the number of outflows we also crudely estimate the star formation efficiency in L 1495, finding it to be compatible with a canonical value of 10-15%. We note that molecular outflow-driving sources have redder near-IR colours than their HH jet-driving counterparts. We also find that the smaller, denser cores are associated with the more massive outflows, as one might expect if mass build-up in the flow increases with the collapse and contraction of the protostellar envelope.

Accepted by MNRAS

http://www.jach.hawaii.edu/∼cdavis/

The IMF of stellar clusters: effects of accretion and feedback

Sami Dib[1], Mohsen Shadmehri[2], Paolo Padoan[3], Maheswar G.[4], D. K. Ojha[5] and Fazeleh Khajenabi[6]

[1] Service d'Astrophysique, DSM/Irfu, CEA/Saclay, F-91191, Gif-sur-Yvette, Cedex, France
[2] Department of Mathematical Physics, National University Ireland, Co kildare, Maynooth, Ireland
[3] ICREA-ICC, University of Barcelona, Spain
[4] Aryabhatta Research Institute of Observational Sciences, Manora Peak, Nainital 263129, India
[5] Tata Institute for Fundamental Research (TIFR), Homi Bhabha Road, Mumbai-400005, India
[6] School of Physics, University College Dublin, Belfield, Dublin 4, Ireland

E-mail contact: sami.dib *at* cea.fr

We have developed a model which describes the co-evolution of the mass function of dense gravitationally bound cores and of the stellar mass function in a protocluster clump. In the model, dense cores are injected, at a uniform rate, at different locations in the clump and evolve under the effect of gas accretion. Gas accretion onto the cores follows a time-dependent accretion rate that describes accretion in a turbulent medium. Once the accretion timescales of cores of a given age, of a given mass, and located at a given distance from the protocluster clumps center exceed their contraction timescales, they are turned into stars. The stellar initial mass function (IMF) is thus built up from successive generations of cores that undergo this accretion-collapse process. We also include the effect of feedback by the newly formed massive stars through their stellar winds. A fraction of the wind's energy is assumed to counter gravity and disperse the gas from the protocluster and as a consequence, quench further star formation. The latter effect sets the final IMF of the cluster. We apply our model to a clump that is expected to resemble the progenitor clump of the Orion Nebula Cluster (ONC). The ONC is the only known cluster for which a well determined IMF exists for masses ranging from the sub-stellar regime to very massive stars. Our model is able to reproduce both the shape and normalization of the ONC's IMF and the mass function of dense submillimeter cores in Orion. The complex features of the ONC's present day IMF, namely, a shallow slope in the mass range $\sim [0.3-2.5]$ M$_\odot$, a steeper slope in the mass range $\sim [2.5-12]$ M$_\odot$, and a nearly flat tail at the high mass end are reproduced. The model predicts a 'rapid' star formation process with an age spread for the stars of $2.3\ \times 10^5$ yr which is consistent with the fact that 80 percent of the ONC's stars have ages of $\lesssim$0.3 Myr. The model also predicts a primordial mass segregation with the most massive stars being born in the region between 2 and 4 times the core radius of the cluster. In parallel, the model also reproduces, at the time the IMF is set and star formation quenched, the mass distribution of dense cores in the Orion star forming complex. We study the effects of varying some of the model parameters on the resulting IMF and we show that the IMF of stellar clusters is expected to show significant variations, provided variations in the clumps and cores physical properties exist.

Accepted by MNRAS main journal

http://arxiv.org/abs/0908.4522

Trapping Solids at the Inner Edge of the Dead Zone: 3-D Global MHD Simulations

Natalia Dzyurkevich[1], Mario Flock[1], Neal J. Turner[2], Hubert Klahr[1] and Thomas Henning[1]

[1] Max-Planck Institute for Astronomy, Koenigstuhl 17, Heidelberg 69117, Germany
[2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109, USA

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

The poorly-ionized interior of the protoplanetary disk or 'dead zone' is the location where dust coagulation processes may be most efficient. However even here, planetesimal formation may be limited by the loss of solid material through radial drift, and by collisional fragmentation of the particles. Both depend on the turbulent properties of the gas. Our aim here is to investigate the possibility that solid particles are trapped at local pressure maxima in the dynamically evolving disk. We perform the first 3-D global non-ideal magnetohydrodynamical (MHD) calculations of a section of the disk treating the turbulence driven by the magneto-rotational instability (MRI). We use the ZeusMP code with a fixed Ohmic resistivity distribution. The domain contains an inner MRI-active region near the young star and an outer midplane dead zone, with the transition between the two modeled by a sharp increase in the magnetic diffusivity. The azimuthal magnetic fields generated in the active zone oscillate over time, changing sign about every 150 years. We thus observe the radial structure of the 'butterfly pattern' seen previously in local shearing-box simulations. The mean magnetic field diffuses from the active zone into the dead zone, where the Reynolds stress nevertheless dominates, giving a residual α between 10^{-4} and 10^{-3}. The greater total accretion stress in the active zone leads to a net reduction in the surface density, so that after 800 years an approximate steady state is reached in which a local radial maximum in the midplane pressure lies near the transition radius. We also observe the formation of density ridges within the active zone. The dead zone in our models possesses a mean magnetic field, significant Reynolds stresses and a steady local pressure maximum at the inner edge, where the outward migration of planetary embryos and the efficient trapping of solid material are possible.

Accepted by A&A

http://arxiv.org/pdf/1002.2521

Comparing the statistics of interstellar turbulence in simulations and observations: Solenoidal versus compressive turbulence forcing

C. Federrath[1,2,3], J. Roman-Duval[4,5], R. S. Klessen[1], W. Schmidt[6,7] and M.-M. Mac Low[2,3]

[1] Zentrum für Astronomie der Universität Heidelberg, Institut für Theoretische Astrophysik, Albert-Ueberle-Str. 2, D-69120 Heidelberg, Germany
[2] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[3] Department of Astrophysics, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024-5192, USA
[4] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[5] Astronomy Department, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, USA
[6] Institut für Astrophysik, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany
[7] Lehrstuhl für Astronomie, Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland,

D-97074 Würzburg, Germany

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

Density and velocity fluctuations on virtually all scales observed with modern telescopes show that molecular clouds (MCs) are turbulent. The forcing and structural characteristics of this turbulence are, however, still poorly understood. To shed light on this subject, we study two limiting cases of turbulence forcing in numerical experiments: solenoidal (divergence-free) forcing and compressive (curl-free) forcing, and compare our results to observations. We solve the equations of hydrodynamics on grids with up to 1024^3 cells for purely solenoidal and purely compressive forcing. Eleven lower-resolution models with different forcing mixtures are also analysed. Using Fourier spectra and Δ-variance, we find velocity dispersion–size relations consistent with observations and independent numerical simulations, irrespective of the type of forcing. However, compressive forcing yields stronger compression at the same RMS Mach number than solenoidal forcing, resulting in a three times larger standard deviation of volumetric and column density probability distributions (PDFs). We compare our results to different characterisations of several observed regions, and find evidence of different forcing functions. Column density PDFs in the Perseus MC suggest the presence of a mainly compressive forcing agent within a shell, driven by a massive star. Although the PDFs are close to log-normal, they have non-Gaussian skewness and kurtosis caused by intermittency. Centroid velocity increments measured in the Polaris Flare on intermediate scales agree with solenoidal forcing on that scale. However, Δ-variance analysis of the column density in the Polaris Flare suggests that turbulence is driven on large scales, with a significant compressive component on the forcing scale. This indicates that, although likely driven with mostly compressive modes on large scales, turbulence can behave like solenoidal turbulence on smaller scales. Principal component analysis of G216-2.5 and most of the Rosette MC agree with solenoidal forcing, but the interior of an ionised shell within the Rosette MC displays clear signatures of compressive forcing. We conclude that the strong dependence of the density PDF on the type of forcing must be taken into account in any theory using the PDF to predict properties of star formation. We supply a quantitative description of this dependence. We find that different observed regions show evidence of different mixtures of compressive and solenoidal forcing, with more compressive forcing occurring primarily in swept-up shells. Finally, we emphasise the role of the sonic scale for protostellar core formation, because core formation close to the sonic scale would naturally explain the observed subsonic velocity dispersions of protostellar cores.

Accepted by A&A

http://cdsads.u-strasbg.fr/abs/2009arXiv0905.1060F

Star Formation History of a Young Super-Star Cluster in NGC 4038/39: Direct Detection of Low Mass Pre-Main Sequence Stars

Julia Greissl[1], Michael R. Meyer[1,2], Micol Christopher[3] and Nick Scoville[3]

[1] Steward Observatory, The University of Arizona, Tucson, AZ 85721, USA
[2] Institute for Astronomy, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093, Zrich, Switzerland
[3] California Institute of Techology, Pasadena, CA 91125, USA

E-mail contact: jgreissl *at* as.arizona.edu

We present an analysis of the near-infrared spectrum of a young massive star cluster in the overlap region of the interacting galaxies NGC 4038/39 using population synthesis models. Our goal is to model the cluster population as well as provide rough constraints on its initial mass function (IMF). The cluster shows signs of youth such as thermal radio emission and strong hydrogen emission lines in the near-infrared. Late-type absorption lines are also present which are indicative of late-type stars in the cluster. The strength and ratio of these absorption lines cannot be reproduced through either late-type pre-main sequence (PMS) stars or red supergiants alone. Thus we interpret the spectrum as a superposition of two star clusters of different ages, which is feasible since the 1" spectrum encompasses a physical region of 90 pc and radii of super-star clusters are generally measured to be a few parsecs. One cluster is young ($\leq$ 3 Myr) and is responsible for part of the late-type absorption features, which are due to PMS stars in the cluster, and the hydrogen emission lines. The second cluster is older (6 Myr - 18 Myr) and is needed to reproduce the overall depth of the late-type absorption features in the spectrum. Both are required to accurately reproduce the near-infrared spectrum of the object. Thus we have directly detected PMS objects in an unresolved super-star cluster for the first time using a combination of population synthesis models and pre-main sequence tracks. This analysis serves as a testbed of our technique to constrain the low-mass IMF in young super-star clusters as well as an exploration of the star formation history of young UC HII regions.

Accepted by The Astrophysical Journal

http://arxiv.org/abs/1001.1964

Outflow - Core Interaction in Barnard 1

Masaaki Hiramatsu[1,2], Naomi Hirano[1] and Shigehisa Takakuwa[1]

[1] Academia Sinica Institute of Astronomy and Astrophysics
[2] National Tsing Hua University

E-mail contact: hiramatsu *at* asiaa.sinica.edu.tw

In order to study how outflows from protostars influence the physical and chemical conditions of the parent molecular cloud, we have observed Barnard 1 (B1) main core, which harbors four Class 0 and three Class I sources, in the CO ($J = 1-0$), CH_3OH ($J_K = 2_K - 1_K$), and the SiO ($J = 1-0$) lines using the NRO 45 m telescope. We have identified three CO outflows in this region; one is an elongated ($\sim$ 0.3 pc) bipolar outflow from a Class 0 protostar B1-c in the submillimeter clump SMM 2, another is a rather compact ($\sim$ 0.1 pc) outflow from a Class I protostar B1 IRS in the clump SMM 6, and the other is extended outflow from a Class I protostar in SMM 11. In the western lobe of the SMM 2 outflow, both the SiO and CH_3OH lines show broad redshifted wings with the terminal velocities of 25 km s^{-1} and 13 km s^{-1}, respectively. It is likely that the shocks caused by the interaction between the outflow and ambient gas enhance the abundance of SiO and CH_3OH in the gas phase. The total energy input rate by the outflows ($1.1 \times 10^{-3} L_\odot$) is smaller than the energy loss rate ($8.5 \times 10^{-3} L_\odot$) through the turbulence decay in B1 main core, which suggests that the outflows can not sustain the turbulence in this region. Since the outflows are energetic enough to compensate the dissipating turbulence energy in the neighboring, more evolved star forming region NGC 1333, we suggest that the turbulence energy balance depends on the evolutionary state of the star formation in molecular clouds.

Accepted by Astrophysical Journal

http://arxiv.org/abs/1001.5107

The exceptional Herbig Ae star HD 101412: The first detection of resolved magnetically split lines and the presence of chemical spots in a Herbig star

S. Hubrig[1], M. Schöller[2], I. Savanov[3], J. F. González[4], C. R. Cowley[5], O. Schütz[6], R. Arlt[1] and G. Rüdiger[1]

[1] Astrophysikalisches Institut Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany
[2] European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany
[3] Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya 48, Moscow 119017, Russia
[4] Instituto de Ciencias Astronomicas, de la Tierra, y del Espacio (ICATE), 5400 San Juan, Argentina
[5] Department of Astronomy, University of Michigan, Ann Arbor, MI 48109-1042, USA
[6] European Southern Observatory, Alonso de Cordova 3107, Casilla 19001, Santiago 19, Chile

E-mail contact: shubrig *at* aip.de

In our previous search for magnetic fields in Herbig Ae stars, we pointed out that HD 101412 possesses the strongest magnetic field among the Herbig Ae stars and hence is of special interest for follow-up studies of magnetism among young pre-main-sequence stars. We obtained high-resolution, high signal-to-noise UVES and a few lower quality HARPS spectra revealing the presence of resolved magnetically split lines. HD 101412 is the first Herbig Ae star for which the rotational Doppler effect was found to be small in comparison to the magnetic splitting and several spectral lines observed in unpolarized light at high dispersion are resolved into magnetically split components. The measured mean magnetic field modulus varies from 2.5 to 3.5 kG, while the mean quadratic field was found to vary in the range of 3.5 to 4.8 kG. To determine the period of variations, we used radial velocity, equivalent width, line width, and line asymmetry measurements of variable spectral lines of several elements, as well as magnetic field measurements. The period determination was done using the Lomb-Scargle method. The most pronounced variability was detected for spectral lines of He I and the iron peak elements, whereas the spectral lines of CNO elements are only slightly variable. From spectral variations and magnetic field measurements we derived a potential rotation period P_{rot}=13.86 d, which has to be proven in future studies with a larger number of observations. It is the first time that the presence of

element spots is detected on the surface of a Herbig Ae/Be star. Our previous study of Herbig Ae stars revealed a trend towards stronger magnetic fields for younger Herbig Ae stars, confirmed by statistical tests. This is in contrast to a few other (non-statistical) studies claiming that magnetic Herbig Ae stars are progenitors of the magnetic Ap stars. New developments in MHD theory show that the measured magnetic field strengths are compatible with a current-driven instability of toroidal fields generated by differential rotation in the stellar interior. This explanation for magnetic intermediate-mass stars could be an alternative to a frozen-in fossil field.

Accepted by Astronomische Nachrichten

http://arxiv.org/abs/1002.3037

A detailed study of the rise phase of a long duration X-ray flare in the young star TWA 11B

J. Lopez-Santiago[1], I. Crespo-Chacon[1], G. Micela[2] and F. Reale[3,2]

[1] Departamento de Astrofisica y CC. de la Atmosfera, Universidad Complutense de Madrid, E-28040 Madrid, Spain
[2] INAF - Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, I-90134 Palermo, Italy
[3] Dipartimento di Scienze Fisiche e Astronomiche, Sezione di Astronomia, Universita di Palermo, Piazza Parlamento 1, I-90134 Palermo, Italy

E-mail contact: jls *at* astrax.fis.ucm.es

We analyzed a long duration flare observed in a serendipitous XMM-Newton detection of the M star CD-39 7717B (TWA 11B), member of the young stellar association TW Hya ($\sim$ 8 Myr). Only the rise phase (with a duration of $\sim$ 35 ks) and possibly the flare peak were observed. We took advantage of the high count-rate of the X-ray source to carry out a detailed analysis of its spectrum during the whole exposure. After a careful analysis, we interpreted the rise phase as resulting from the ignition of a first group of loops (event A) which triggered a subsequent two-ribbon flare (event B). Event A was analyzed using a single-loop model, while a two-ribbon model was applied for event B. Loop semi-lengths of $\sim 4R_*$ were obtained. Such large structures had been previously observed in very young stellar objects ($\sim 1-4$ Myr). This is the first time that they have been inferred in a slightly more evolved star. The fluorescent iron emission line at 6.4 keV was detected during event B. Since TWA 11B seems to have no disk, the most plausible explanation found for its presence in the X-ray spectrum of this star is collisional- or photo-ionization. As far as we are concerned, this is only the third clear detection of Fe photospheric fluorescence in stars other than the Sun.

Accepted by ApJ

Water Vapor in the Inner 25 AU of a Young Disk around a Low-Mass Protostar

Jes K. Jørgensen[1] and Ewine F. van Dishoeck[2,3]

[1] Argelander-Institut für Astronomie, University of Bonn, Auf dem Hügel 71, 53121 Bonn, Germany
(Current address: Centre for Star and Planet Formation, University of Copenhagen, Denmark)
[2] Leiden Observatory, Leiden University, PO Box 9513, NL-2300 RA Leiden, The Netherlands
[3] Max Planck Institut für extraterrestrische Physik, Giessenbachstrasse, D-85748 Garching, Germany

E-mail contact: jes *at* snm.ku.dk

Water is one of the key molecules in the physical and chemical evolution of star- and planet-forming regions. We here report the first spatially resolved observation of thermal emission of (an isotopologue of) water with the Plateau de Bure Interferometer toward the deeply embedded Class 0 protostar NGC 1333-IRAS4B. The observations of the $H_2^{18}O$ $3_{1,3}-2_{2,0}$ transition at 203.4 GHz resolve the emission of water toward this source with an extent of about 0.2$''$ corresponding to the inner 25 AU (radius). The $H_2^{18}O$ emission reveals a tentative velocity gradient perpendicular to the extent of the protostellar outflow/jet probed by observations of CO rotational transitions and water masers. The line is narrow $\approx$ 1 km s^{-1} (FWHM), significantly less than what would be expected for emission from an infalling envelope or accretion shock, but consistent with emission from a disk seen at a low inclination angle. The water column density inferred from these data suggests that the water emitting gas is a thin warm layer containing about 25 $M_{\rm Earth}$ of material, 0.03% of the total disk mass traced by continuum observations.

Published in ApJ 710, L72, 2010

http://arxiv.org/abs/1001.1532

On the Role of Disks in the Formation of Stellar Systems: A Numerical Parameter Study of Rapid Accretion

Kaitlin M. Kratter[1], Christopher D. Matzner[1], Mark R. Krumholz[2] and Richard I. Klein[3,4]

[1] University of Toronto
[2] University of California, Santa Cruz
[3] University of California, Berkeley
[4] Lawrence Livermore National Laboratory

E-mail contact: kratter *at* astro.utoronto.ca

We study rapidly accreting, gravitationally unstable disks with a series of idealized global, numerical experiments using the code ORION. Our numerical parameter study focuses on protostellar disks, showing that one can predict disk behavior and the multiplicity of the accreting star system as a function of two dimensionless parameters which compare the infall rate to the disk sound speed and orbital period. Although gravitational instabilities become strong, we find that fragmentation into binary or multiple systems occurs only when material falls in several times more rapidly than the canonical isothermal limit. The disk-to-star accretion rate is proportional to the infall rate and governed by gravitational torques generated by low-m spiral modes. We also confirm the existence of a maximum stable disk mass: disks that exceed 50% of the total system mass are subject to fragmentation and the subsequent formation of binary companions.

Accepted by ApJ

http://adsabs.harvard.edu/abs/2010ApJ...708.1585K

The Runts of the Litter: Why Planets Formed Through Gravitational Instability Can Only Be Failed Binary Stars

Kaitlin M. Kratter[1], Ruth A. Murray-Clay[2] and Andrew N. Youdin[3]

[1] University of Toronto
[2] Harvard-Smithsonian Center for Astrophysics
[3] Canadian Institute for Theoretical Astrophysics

E-mail contact: kratter *at* astro.utoronto.ca

Recent direct imaging discoveries suggest a new class of massive, distant planets around A stars. These widely separated giants have been interpreted as signs of planet formation driven by gravitational instability, but the viability of this mechanism is not clear-cut. In this paper, we first discuss the local requirements for fragmentation and the initial fragment mass scales. We then consider whether the fragment's subsequent growth can be terminated within the planetary mass regime. Finally, we place disks in the larger context of star formation and disk evolution models. We find that in order for gravitational instability to produce planets, disks must be atypically cold in order to reduce the initial fragment mass. In addition, fragmentation must occur during a narrow window of disk evolution, after infall has mostly ceased, but while the disk is still sufficiently massive to undergo gravitational instability. Under more typical conditions, disk-born objects will likely grow well above the deuterium burning planetary mass limit. We conclude that if planets are formed by gravitational instability, they must be the low-mass tail of the distribution of disk-born companions. To validate this theory, ongoing direct imaging surveys must find a greater abundance of brown dwarf and M-star companions to A stars. Their absence would suggest planet formation by a different mechanism such as core accretion, which is consistent with the debris disks detected in these systems.

Accepted by ApJ

http://www.iop.org/EJ/abstract/0004-637X/710/2/1375/

Gas Absorption in the KH 15D System: Further Evidence for Dust Settling in the Circumbinary Disk

S. M. Lawler[1,7], W. Herbst[1], S. Redfield[1], C. M. Hamilton[2], C. M. Johns-Krull[3], J. N. Winn[4], J. A. Johnson[5] and R. Mundt[6]

[1] Astronomy Department, Wesleyan University, Middletown, CT 06459, USA
[2] Physics and Astronomy Department, Dickinson College, Carlisle, PA 17013, USA
[3] Department of Physics and Astronomy, Rice University, 6100 Main Street, Houston, TX 77005, USA [4] Department of Physics and Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
[5] Department of Astrophysics, California Institute of Technology, MC 249-17, Pasadena, CA 91125, USA
[6] Max-Planck-Institute für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[7] Current address: Department of Physics and Astronomy, University of British Columbia, 6244 Agricultural Road, Vancouver, BC V6T 1Z1 Canada

E-mail contact: lawler *at* astro.ubc.ca

Na I D lines in the spectrum of the young binary KH 15D have been analyzed in detail. We find an excess absorption component that may be attributed to foreground interstellar absorption, and to gas possibly associated with the solids in the circumbinary disk. The derived column density is log $N_{\rm NaI} = 12.5$ cm^{-2}, centered on a radial velocity that is consistent with the systemic velocity. Subtracting the likely contribution of the ISM leaves log $N_{\rm NaI} \sim 12.3$ cm^{-2}. There is no detectable change in the gas column density across the "knife edge" formed by the opaque grain disk, indicating that the gas and solids have very different scale heights, with the solids being highly settled. Our data support a picture of this circumbinary disk as being composed of a very thin particulate grain layer composed of millimeter-sized or larger objects that are settled within whatever remaining gas may be present. This phase of disk evolution has been hypothesized to exist as a prelude to the formation of planetesimals through gravitational fragmentation, and is expected to be short-lived if much gas were still present in such a disk. Our analysis also reveals the presence of excess Na I D emission relative to the comparison spectrum at the radial velocity of the currently visible star that plausibly arises within the magnetosphere of this still-accreting young star.

Accepted by Astrophysical Journal

http://arxiv.org/abs/1002.0302

High Resolution Observations of Dust Continuum Emission at 340 GHz from the Low-mass T Tauri Star FN Tauri

Munetake Momose[1], Nagayoshi Ohashi[2], Tomoyuki Kudo[3], Motohide Tamura[3] and Yoshimi Kitamura[4]

[1] College of Science, Ibaraki University, Bunkyo 2-1-1, Mito, Ibaraki 310-8512, Japan
[2] Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 10617, Taiwan, R. O. C.
[3] National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan
[4] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan

E-mail contact: momose *at* mx.ibaraki.ac.jp

FN Tau is a rare example of very low-mass T Tauri stars that exhibits a spatially resolved nebulosity in near-infrared scattering light. To directly derive the parameters of a circumstellar disk around FN Tau, observations of dust continuum emission at 340 GHz are carried out with the Submillimeter Array (SMA). A point-like dust continuum emission was detected with a synthesized beam of $\sim 0.7''$ in FWHM. From the analysis of the visibility plot, the radius of the emission is estimated to be $\leq 0.29''$, corresponding to 41 AU. This is much smaller than the radius of the nebulosity, $1.85''$ for its brighter part at 1.6 μm. The 340 GHz continuum emission observed with the SMA and the photometric data at $\lambda \leq 70$ μm are explained by a power-law disk model whose outer radius and mass are 41 AU and $(0.24 - 5.9) \times 10^{-3}$ $M_\odot$, respectively, if the exponent of dust mass opacity (β) is assumed to be $0 - 2$. The disk model cannot fully reproduce the flux density at 230 GHz obtained with the IRAM 30-meter telescope, suggesting that there is another extended "halo" component that is missed in the SMA observations. By requiring the halo not to be detected with the SMA, the lower limit to the size of the halo is evaluated to be between 174 AU and 574 AU, depending on the assumed β value. This size is comparable to the near-infrared nebulosity, implying that the halo

unseen with the SMA corresponds to the origin of the near-infrared nebulosity. The halo can contain mass comparable to or at most 8 times greater than that of the inner power-law disk, but its surface density should be lower than that at the outer edge of the power-law disk by more than one order of magnitude. The physical nature of the halo is unclear, but it may be the periphery of a flared circumstellar disk that is not described well in terms of a power-law disk model, or a remnant of a protostellar envelope having flattened structure.

Accepted by The Astrophysical Journal

http://arxiv.org/abs/1002.2462

Confirmation of a recent bipolar ejection in the very young hierarchical multiple system IRAS 16293–2422

Gerardo Pech[1], Laurent Loinard[1], Claire J. Chandler[2], Luis F. Rodriguez[1], Paola D'Alessio[1], Crystal L. Brogan[3], David J. Wilner[4] and Paul T.P. Ho[4]

[1] Centro de Radiostronomía y Astrofísica, Universidad Nacional Autónoma de México, 58089 Morelia, México
[2] National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, USA
[3] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903-2475, USA
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: g.pech *at* crya.unam.mx

We present and analyze two new high-resolution (∼0.3"), high-sensitivity ($\sim 50\ \mu$Jy beam^{-1}) Very Large Array 3.6 cm observations of IRAS 16293–2422 obtained in 2007 August and 2008 December. The components A2α and A2β recently detected in this system are still present, and have moved roughly symmetrically away from source A2 at a projected velocity of 30–80 km s^{-1}. This confirms that A2α and A2β were formed as a consequence of a very recent bipolar ejection from A2. Powerful bipolar ejections have long been known to occur in low-mass young stars, but this is –to our knowledge– the first time that such a dramatic one is observed from its very beginning. Under the reasonable assumption that the flux detected at radio wavelengths is optically thin free-free emission, one can estimate the mass of each ejecta to be of the order of $10^{-8}\ M_\odot$. If the ejecta were created as a consequence of an episode of enhanced mass loss accompanied by an increase in accretion onto the protostar, then the total luminosity of IRAS 16293–2422 ought to have increased by 10–60% over the course of at least several months. Between A2α and A2β, component A2 has reappeared, and the relative position angle between A2 and A1 is found to have increased significantly since 2003–2005. This strongly suggests that A1 is a protostar rather than a shock feature, and that the A1/A2 pair is a tight binary system. Including component B, IRAS 16293–2422 therefore appears to be a very young hierarchical multiple system.

Accepted by The Astrophysical Journal

http://arxiv.org/abs/1002.2417

Direct observation of a sharp transition to coherence in Dense Cores

Jaime E. Pineda[1], Alyssa A. Goodman[1], Héctor G. Arce[2], Paola Caselli[3], Jonathan B. Foster[1,4], Philip C. Myers[1], and Erik W. Rosolowsky[5]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA
[2] Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520-8101, USA
[3] School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK
[4] Current address: Institute for Astrophysical Research, 725 Commonwealth Avenue, Boston, MA 02215, USA
[5] University of British Columbia Okanagan, 3333 University Way, Kelowna, BC V1V 1V7, Canada

E-mail contact: jpineda *at* cfa.harvard.edu

We present NH_3 observations of the B5 region in Perseus obtained with the Green Bank Telescope (GBT). The map covers a region large enough ($\sim 11' \times 14'$) that it contains the entire dense core observed in previous dust continuum surveys. The dense gas traced by NH_3(1,1) covers a much larger area than the dust continuum features found in bolometer observations. The velocity dispersion in the central region of the core is small, presenting subsonic non-thermal motions which are independent of scale. However, it is thanks to the coverage and high sensitivity of the observations that we present the detection, for the first time, of the transition between the coherent core and the dense

but more turbulent gas surrounding it. This transition is sharp, increasing the velocity dispersion by a factor of 2 in less than 0.04 pc (the 31″ beam size at the distance of Perseus, ∼250 pc). The change in velocity dispersion at the transition is $\approx 3\ \mathrm{km\,s^{-1}\,pc^{-1}}$. The existence of the transition provides a natural definition of dense core: the region with nearly-constant subsonic non-thermal velocity dispersion. From the analysis presented here we can not confirm nor rule out a corresponding sharp density transition.

Accepted by ApJ Letters

http://arxiv.org/abs/1002.2946

High-Resolution Submillimeter Multiple Observations of G19.61-0.23: Small-Scale Chemistry

Sheng-Li Qin[1], Yuefang Wu[2], Maohai Huang[1], Gang Zhao[1], Di Li[3], Jun-Jie Wang[1] and Sheng Chen[1]

[1] National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012, China
[2] Department of Astronomy, Peking University, Beijing, 100871, China
[3] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

E-mail contact: slqin *at* bao.ac.cn

We present the Submillimeter Array (SMA) observations of molecular lines at 330 and 340 GHz toward G19.61-0.23. The SMA observations have a spatial resolution of ∼2″ and a bandpass of 2×2 GHz bandwidth. With the SMA data, we have detected 131 molecular transitions. Ninety-four molecular transitions from 17 species and their isotopomers are identified, including complex organic molecules and simple linear molecules. Most of the complex molecules (CH_3OH, $^{13}CH_3OH$, C_2H_5OH, $HCOOCH_3$, HNCO, NH_2CHO, CH_3CN, and CH_3CH_2CN) have a sufficient number of transitions in this observation to allow analysis using the rotational temperature diagram method. The results from rotation temperature diagram fitting have shown that the complex nitrogen-bearing molecules have higher rotation temperatures (296–609 K) and lower column densities (6.5×10^{15}–6.4×10^{16} cm^{-2}). In contrast, the temperatures and column densities of the complex oxygen-bearing molecules range from 95 to 151 K, and from 1.1×10^{16} to 5.2×10^{17} cm^{-2}, respectively. The H_2 column density is estimated from the submillimeter continuum, and the fractional abundances of various species relative to H_2 are calculated. The oxygen-bearing molecules have higher fractional abundances than those of the nitrogen-bearing molecules. The different gas temperatures and fractional abundances suggest a chemical differentiation between oxygen and nitrogen-bearing molecules. The images of the spatial distribution of different species have shown that the oxygen-bearing and nitrogen-bearing molecules peak at different positions. Through comparing the rotation temperatures and fractional abundances with the spatial distributions of the molecules, we discuss possible chemical processes for producing the complex molecules, as well as nitrogen and oxygen differentiation in G19.61-0.23.

Published by ApJ, 711, 399, 2010

Diffusion of magnetic field and removal of magnetic flux from clouds via turbulent reconnection

R. Santos-Lima[1], A. Lazarian[2], E. M. de Gouveia Dal Pino[1] and J. Cho[2,3]

[1] Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, R. do Matão, 1226, São Paulo, SP 05508-090, Brazil
[2] Department of Astronomy, University of Wisconsin, Madison, WI 53706, USA
[3] Dept. of Astronomy and Space Science, Chungnam National Univ., Daejeon, Korea

E-mail contact: rlima *at* astro.iag.usp.br

The diffusion of astrophysical magnetic fields in conducting fluids in the presence of turbulence depends on whether magnetic fields can change their topology via reconnection in highly conducting media. Recent progress in understanding fast magnetic reconnection in the presence of turbulence is reassuring that the magnetic field behavior in computer simulations and turbulent astrophysical environments is similar, as far as magnetic reconnection is concerned. This makes it meaningful to perform MHD simulations of turbulent flows in order to understand the diffusion of magnetic field in astrophysical environments. Our studies of magnetic field diffusion in turbulent medium reveal interesting new phenomena. First of all, our three-dimensional MHD simulations initiated with anti-correlating magnetic field and gaseous density exhibit at later times a de-correlation of the magnetic field and density, which corresponds well

to the observations of the interstellar media. While earlier studies stressed the role of either ambipolar diffusion or time-dependent turbulent fluctuations for de-correlating magnetic field and density, we get the effect of permanent de-correlation with one fluid code, i.e., without invoking ambipolar diffusion. In addition, in the presence of gravity and turbulence, our three-dimensional simulations show the decrease of the magnetic flux-to-mass ratio as the gaseous density at the center of the gravitational potential increases.We observe this effect both in the situations when we start with equilibrium distributions of gas and magnetic field and when we follow the evolution of collapsing dynamically unstable configurations. Thus the process of turbulent magnetic field removal should be applicable both to quasi-static subcritical molecular clouds and cores and violently collapsing supercritical entities. The increase of the gravitational potential as well as the magnetization of the gas increases the segregation of the mass and magnetic flux in the saturated final state of the simulations, supporting the notion that the reconnection-enabled diffusivity relaxes the magnetic field + gas system in the gravitational field to its minimal energy state. This effect is expected to play an important role in star formation, from its initial stages of concentrating interstellar gas to the final stages of the accretion to the forming protostar. In addition, we benchmark our codes by studying the heat transfer in magnetized compressible fluids and confirm the high rates of turbulent advection of heat obtained in an earlier study.

Accepted by Astrophysical Journal

http://arxiv.org/abs/0910.1117

On the extreme positive star-formation feedback condition in SCUBA sources

Sergiy Silich[1], Guillermo Tenorio-Tagle[1,2], Casiana Muñoz-Tuñón[3], Filiberto Hueyotl-Zahuantitla[1], Richard Wünsch[4] and Jan Palous[4]

[1] Instituto Nacional de Astrofísica Optica y Electrónica, AP 51, 72000 Puebla, México
[2] Sackler Visiting Fellow at the Institute of Astronomy, University of Cambridge, U.K.
[3] Instituto de Astrofísica de Canarias, E 38200 La Laguna, Tenerife, Spain
[4] Astronomical Institute, Academy of Sciences of the Czech Republic, Bocní II 1401, 141 31 Prague, Czech Republic

E-mail contact: silich *at* inaoep.mx

We present a detailed study of the hydrodynamics of the matter reinserted by massive stars via stellar winds and supernovae explosions in young assembling galaxies. We show that the interplay between the thermalization of the kinetic energy provided by massive stars, radiative cooling of the thermalized plasma and the gravitational pull of the host galaxy, lead to three different hydrodynamic regimes. These are: a) The quasi-adiabatic supergalactic winds. b) The bimodal flows, with mass accumulation in the central zones and gas expulsion from the outer zones of the assembling galaxy. c) The gravitationally bound regime, for which all of the gas returned by massive stars remains bound to the host galaxy and is likely to be reprocessed into futher generations of stars. Which of the three possible solutions takes place, depends on the mass of the star forming region its mechanical luminosity (or star formation rate) and its size. The model predicts that massive assembling galaxies with large star formation rates similar to those detected in SCUBA sources (~ 1000 $M_\odot$ yr^{-1}) are likely to evolve in a positive star-formation feedback condition, either in the bimodal, or in the gravitationally bound regime. This implies that star formation in these sources may have little impact on the intergalactic medium and result instead into a fast interstellar matter enrichment, as observed in high redshift quasars.

Accepted by ApJ

http://arxiv.org/abs/1001.3063

ISM Dust Grains and N-band Spectral Variability in the Spatially Resolved Subarcsecond Binary UY Aur

Andrew Skemer[1], Laird Close[1], Philip Hinz[1], William Hoffmann[1], Thomas Greene[2], Jared Males[1] and Tracy Beck[3]

[1] Steward Observatory, University of Arizona
[2] NASA Ames Research Center
[3] Space Telescope Science Institute

E-mail contact: askemer *at* as.arizona.edu

The 10 micron silicate feature is an essential diagnostic of dust-grain growth and planet formation in young circum-

stellar disks. The Spitzer Space Telescope has revolutionized the study of this feature, but due to its small (85cm) aperture, it cannot spatially resolve small/medium separation binaries (less than ∼3" or ∼420 AU) at the distances of the nearest star-forming regions (∼140 pc). Large, 6-10m ground-based telescopes with mid-infrared instruments can resolve these systems.

In this paper, we spatially resolve the 0.88" binary, UY Aur, with MMTAO/BLINC-MIRAC4 mid-infrared spectroscopy. We then compare our spectra to Spitzer/IRS (unresolved) spectroscopy, and resolved images from IRTF/MIRAC2, Keck/OSCIR and Gemini/Michelle, which were taken over the past decade. We find that UY Aur A has extremely pristine, ISM-like grains and that UY Aur B has an unusually shaped silicate feature, which is probably the result of blended emission and absorption from foreground extinction in its disk. We also find evidence for variability in both UY Aur A and UY Aur B by comparing synthetic photometry from our spectra with resolved imaging from previous epochs. The photometric variability of UY Aur A could be an indication that the silicate emission itself is variable, as was recently found in EX Lupi. Otherwise, the thermal continuum is variable, and either the ISM-like dust has never evolved, or it is being replenished, perhaps by UY Aur's circumbinary disk.

Accepted by the Astrophysical Journal

http://lanl.arxiv.org/abs/1001.5036

HST/ACS Hα Imaging of the Carina Nebula: Outflow Activity Traced by Irradiated Herbig-Haro Jets

Nathan Smith[1], John Bally[2] and Nolan R. Walborn[3]

[1] Department of Astronomy, University of California, 601 Campbell Hall, Berkeley, CA 94720, USA
[2] Center for Astrophysics and Space Astronomy, University of Colorado, 389 UCB, Boulder, CO 80309, USA
[3]Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218, USA

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

We report the discovery of new Herbig-Haro (HH) jets in the Carina Nebula, and we discuss the protostellar outflow activity of a young OB association. These are the first results of an Hα imaging survey of Carina conducted with the *Hubble Space Telescope*/Advanced Camera for Surveys. Adding to the one previously known example (HH 666), we detect 21 new HH jets, plus 17 new candidate jets, ranging in length from 0.005 to 3 pc. Using the Hα emission measure to estimate jet densities, we derive jet mass-loss rates ranging from 8×10^{-9} to $\sim10^{-6}$ $M_\odot$ yr^{-1}, but a comparison to the distribution of jet mass-loss rates in Orion suggests that we may be missing a large fraction of the jets below 10^{-8} $M_\odot$ yr^{-1}. A key qualitative result is that even some of the smallest dark globules with sizes of $\lesssim1''$ (0.01 pc) are active sites of ongoing star formation because we see HH jets emerging from them, and that these offer potential analogs to the cradle of our Solar System because of their proximity to dozens of imminent supernovae that will enrich them with radioactive nuclides like ^{60}Fe. Whereas most proplyd candidates identified from ground-based data are dark cometary globules, *HST* images now reveal proplyd structures in the core of the Tr 14 cluster, only 0.1–0.2 pc from several extreme O-type stars. Throughout Carina, some HH jets have axes bent away from nearby massive stars, while others show no bend, and still others are bent *toward* the massive stars. These jet morphologies serve as "wind socks"; strong photoevaporative flows can shape the jets, competing with the direct winds and radiation from massive stars. We find no clear tendency for jets to be aligned perpendicular to the axes of dust pillars. Finally, even allowing for a large number of jets that may escape detection, we find that HH jets are negligible to the global turbulence of the surrounding region, which is driven by massive star feedback.

Accepted by MNRAS

A deep optical/near-infrared catalog of Serpens

L. Spezzi[1], B. Merin[2], I. Oliveira[3], E.F. van Dishoeck[4] and J.M. Brown[5]

[1] Research and Scientific Support Department, European Space Agency (ESA-ESTEC), P.O. Box 299, 2200 AG Noordwijk, The Netherlands
[2] European Space Astronomy Center, European Space Agency (ESA-ESAC), P.O. Box Apdo. de correos 78, 28691 Villanueva de la Canada, Madrid, Spain
[3] California Institute of Technology, Division for Geological and Planetary Sciences, MS 150-21, Pasadena, CA 91125, USA
[4] Sterrewacht Leiden, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands

[5] Max Planck Institut für Extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany

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

We present a deep optical/near-infrared imaging survey of the Serpens molecular cloud. This survey constitutes the complementary optical data to the Spitzer "Core To Disk" (c2d) Legacy survey in this cloud. The survey was conducted using the Wide Field Camera at the Isaac Newton Telescope. About 0.96 square degrees were imaged in the R and Z filters, covering the entire region where most of the young stellar objects identified by the c2d survey are located. 26524 point-like sources were detected in both R and Z bands down to $R \approx 24.5$ mag and $Z \approx 23$ mag with a signal-to-noise ratio better than 3. The 95% completeness limit of our catalog corresponds to 0.04 $M_\odot$ for members of the Serpens star forming region (age 2 Myr and distance 260 pc) in the absence of extinction. Adopting the typical extinction of the observed area ($A_V \approx 7$ mag), we estimate a 95% completeness level down to $M \approx 0.1$ $M_\odot$. The astrometric accuracy of our catalog is 0.4 arcsec with respect to the 2MASS catalog. Our final catalog contains J2000 celestial coordinates, magnitudes in the R and Z bands calibrated to the SDSS photometric system and, where possible, JHK_S magnitudes from 2MASS for sources in 0.96 square degrees in the direction of Serpens. This data product has been already used within the frame of the c2d Spitzer Legacy Project analysis in Serpens to study the star/disk formation and evolution in this cloud; here we use it to obtain new indications of the disk-less population in Serpens.

Accepted by A&A

http://arxiv.org/abs/1002.1595

Complex Structure in Class 0 Protostellar Envelopes

John J Tobin[1], Lee Hartmann[1], Hsin-Fang Chiang[2] and Leslie W. Looney[2]

[1] Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA
[2] Department of Astronomy, University of Illinois at Champaign/Urbana, Urbana, IL 61801, USA

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

We use archived IRAC images from the *Spitzer Space Telescope* to show that many Class 0 protostars exhibit complex, irregular, and non-axisymmetric structure within their dusty envelopes. Our 8 μm extinction maps probe some of the densest regions in these protostellar envelopes. Many of the systems are observed to have highly irregular and non-axisymmetric morphologies on scales $\gtrsim$ 1000 AU, with a quarter of the sample exhibiting filamentary or flattened dense structures. Complex envelope structure is observed in regions spatially distinct from outflow cavities, and the densest structures often show no systematic alignment perpendicular to the cavities. These results indicate that mass ejection is not responsible for much of the irregular morphologies we detect; rather, we suggest that the observed envelope complexity is mostly the result of collapse from protostellar cores with initially non-equilibrium structures. The striking non-axisymmetry in many envelopes could provide favorable conditions for the formation of binary systems. We also note that protostars in the sample appear to be formed preferentially near the edges of clouds or bends in filaments, suggesting formation by gravitational focusing.

Accepted by ApJ

http://arxiv.org/abs/1002.2362 http://www.astro.lsa.umich.edu/~jjtobin/Envelopes.pdf

Outflow Feedback Regulated Massive Star Formation in Parsec-Scale Cluster Forming Clumps

P. Wang[1], Z.-Y. Li[2], T. Abel[1] and F. Nakamura[3]

[1] Stanford University
[2] University of Virginia
[3] Niigata University, Japan

E-mail contact: zl4h *at* virginia.edu

We investigate massive star formation in turbulent, magnetized, parsec-scale clumps of molecular clouds including protostellar outflow feedback using three dimensional numerical simulations of effective resolution 2048^3. The calculations are carried out using a block structured adaptive mesh refinement code that solves the ideal MHD equations including self-gravity and implements accreting sink particles. We find that, in the absence of regulation by magnetic

fields and outflow feedback, massive stars form readily in a turbulent, moderately condensed clump of $\sim 1,600\ M_\odot$ (containing $\sim 10^2$ initial Jeans masses), along with a cluster of hundreds of lower mass stars. The massive stars are fed at high rates by (1) transient dense filaments produced by large-scale turbulent compression at early times, and (2) by the clump-wide global collapse resulting from turbulence decay at late times. In both cases, the bulk of the massive star's mass is supplied from outside a 0.1 pc-sized "core" that surrounds the star. In our simulation, the massive star is clump-fed rather than core-fed. The need for large-scale feeding makes the massive star formation prone to regulation by outflow feedback, which directly opposes the feeding processes. The outflows reduce the mass accretion rates onto the massive stars by breaking up the dense filaments that feed the massive star formation at early times, and by collectively slowing down the global collapse that fuels the massive star formation at late times. The latter is aided by a moderate magnetic field of strength in the observed range (corresponding to a dimensionless clump mass-to-flux ratio $\lambda\ \sim$ a few); the field allows the outflow momenta to be deposited more efficiently inside the clump. We conclude that the massive star formation in our simulated turbulent, magnetized, parsec-scale clump is outflow-regulated and clump-fed (ORCF for short). An important implication is that the formation of low-mass stars in a dense clump can affect the formation of massive stars in the same clump, through their outflow feedback on the clump dynamics. In a companion paper, we discuss the properties of the lower mass cluster members formed along with the massive stars, including their mass distribution and spatial clustering.

Accepted by ApJ

https://www.astro.virginia.edu/people//faculty/zl4h/WangLiAbelNakamura.pdf

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).

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

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

EU LASSIE Network - Job Announcements

The European Union has recently approved under Framework 7 the ITN-People network LASSIE; a large interdisciplinary training network in the field of SOLID STATE ASTROCHEMISTRY established with the goal of addressing issues of relevance to the chemical evolution of the Universe. From 01/02/2010 and over the next 4 years, a consortium of 13 experimental and theoretical groups with 5 industrial and 1 outreach partners, led by Professor Martin McCoustra (Heriot-Watt University, Edinburgh, UK), will supply training and research opportunities for up to 28 Early Stage Researchers (ESR, PhD students) and 4 Experienced Researchers (ER, Post-doctoral research assistants) at the following host sites:

Prof. M.R.S. McCoustra Heriot-Watt University, Edinburgh, UK
Dr. L. Hornekaer Aarhus University, Denmark
Prof. J. L. Lemaire Paris Observatory, France
Prof. H. Zacharias University of Mnster, Germany
Dr. C. Jger Max Plank Gesellschaft, Germany
Dr. M. E. Palumbo National Institute for Astrophysics, Catania, Italy
Prof. H. Linnartz Leiden University, Netherlands
Prof. D. Chakarov Chalmers University, Gothenburg, Sweden
Prof. G. Nyman University of Gothenburg, Sweden
Prof. S. D. Price University College London, UK
Prof. N. J. Mason The Open University, UK
Dr. T. A. Field Queen's University, Belfast, UK
Dr. H. J. Fraser Strathclyde University, Glasgow, UK

To qualify as an Early Stage Researcher, candidates must have obtained a Masters Degree or equivalent in Chemistry, Physics, Astronomy or a related Engineering field within the past four years and demonstrate experience in experimental physics, chemical physics, physical chemistry, surface science, computational chemistry and astronomy, or theoretical astrochemistry and astrophysics. Applicants considering themselves as Experienced Researchers must already possess a Doctoral Degree or have at least 4 years of research experience (full time equivalent) since obtaining their Masters Degree. They must also have relevant expertise in one or more of the indicated areas.

The consortium is immediately hiring the first tranche of researchers with 14 ESR and 3 ER positions available NOW. Applications may be considered up to a final deadline of 30th November 2010 for appointment in 2011 of a further 14 ESR and 1 ER positions. All nationalities are eligible to apply but candidates have to fulfil the EU mobility criteria and will be required to work at a site outside their home country.

A more detailed description of the positions available at each host is available by email application to lassie@hw.ac.uk. Potential candidates are requested to obtain this document before sending a detailed application letter, curriculum vitae and contact details of two referees to the relevant local principal investigator.

The closing date for applications is Monday 15th March 2010.

Postdoctoral Research Fellow in Star Formation

(a full-time temporary, exempt position)

The Adler Planetarium is seeking applications for a Postdoctoral Research Fellowship in Star Formation to carry out research in the formation of massive stars and clusters. The applicant will work with the Star Formation group at the Adler, taking a leading role in developing science projects for "Star Formation Zoo," a citizen science program utilizing multi-wavelength galactic plane surveys that will be based on the extremely successful "Galaxy Zoo." Applicants for this position should have experience with infrared observations, data reduction and analysis. Additionally, experience modeling properties of young stellar objects and familiarity with millimeter-wave interferometry is highly desirable. Adler's affiliation with the University of Chicago provides access to the CARMA array and the Apache Point 3.5-m.

The successful applicant will be expected to: 1) lead science projects for the Star Formation Zoo, 2) develop research projects that supplement or complement research interests of the Star Formation group. In addition they will spend 10% time on education and outreach activities related to their research work. The initial appointment will be for three years with a possible one-year extension dependent on successful performance and availability of funding. This position will report to Dr. Grace Wolf-Chase, with oversight by Director of Citizen Science Initiatives Dr. Chris Lintott. Experience with education and outreach is desirable; enthusiasm for engaging the public in science education is essential. Applications will be accepted until the position is filled. Start date is flexible and can be as early as July 1, 2010.

Please email a cover letter, resume, statement of research interests and salary history along with three letters of recommendation to:

Marguerite E. Dawson
Director of Human Resources
Email Address: hr-postdocfellow@adlerplanetarium.org
Telephone Number: 312.322.0591
URL Address: www.adlerplanetarium.org
EEO

Opportunity for Assistant Professor Fellowship in Star & Planet Formation, Stockholm

To strengthen the star & planet formation research at the department of Astronomy, Stockholm University, we are looking for talented researchers interested in applying together with us for a personal, 4 year fellowship from the Swedish Research Council (VR), with a possible extension to 5 years. To be eligible for this fellowship your PhD should be more recent than April 2005 (with some exceptions, e.g. due to parental leave), and you are normally expected to have at least two years of postdoc experience. With the fellowship you will be employed as assistant professor with about 20% teaching/departmental duties (25% if the department agrees to pay the 5th year). It also comes with a personal research budget. The fellowship is prestigious and competitive, with only some 30 granted each year for all of the natural sciences in Sweden, and at most one in astronomy. The decision on the fellowship will be taken by the Swedish National Research Council late 2010, and the position could start any time during 2011.

The star & planet formation research at Stockholm University is mostly observational, using facilities such as ESO/VLT, APEX, and active involvement in Herschel and ALMA. Theoretical/computational work mainly deals with disc-planet interaction and the structure of HII regions. We are also part of the Stockholm University graduate school in Astrobiology, a truly crossdisciplinary collaboration with the departments of physics, geology and molecular biology. We are interested in researchers working observationally and/or theoretically on star formation, planet formation/exo-planets, and/or astrobiology.

Since the actual application to the research council has to be done jointly with the institute (with a deadline in April), we invite those interested in applying to contact one of us before March 15. Please include a CV. You can also contact us for more information: Göran Olofsson (olofsson *at* astro.su.se) or Garrelt Mellema (garrelt *at* astro.su.se).

Astrophysics of Planet Formation

Philip J. Armitage

The discovery of extrasolar planets has given major impetus to the study of planet formation by providing new observational constraints on the architecture of planetary systems. Additionally, our understanding of circumstellar disks has been greatly advanced by powerful new observing techniques and sophisticated computer modeling. The present book provides a detailed account of the physical processes involved in turning a disk into planets, while along the way identifying the issues which are still poorly understood. The book is intended as a graduate level introduction to planet formation. The text is a greatly expanded version of the author's "Lecture Notes on the Formation and Early Evolution of Planetary Systems" (http://arxiv.org/abs/astro-ph/0701485), which will continue to be updated as a free class resource.

The book contains the following chapters:

Cambridge University Press, ISBN-13: 9780521887458, hardback, 294 pages, 2010, US$65.00

Available from: http://www.cambridge.org/catalogue/catalogue.asp?isbn=9780521887458

39th Lige Astrophysical Colloquium
The Multi-Wavelength View of Hot, Massive Stars
Liège, 12 - 16 July, 2010

Registration is now open and you are kindly invited to register and submit abstracts for contributed talks or posters before 15 March 2010. Early registration closes on 15 May 2010. All abstracts will be reviewed by the SOC and the selection will be announced by 15 April 2010. The registration fee is 250 euros and includes refreshments and lunches during the conference, but it does not include transportation or hotel accommodation.

Please note that due to an unfortunate clash with a major sports event (Tour de France 2010 stage arrival near Liège), we had to change the dates of the colloquium compared to the first announcement.

More details about the venue, the travel to Liège as well as contact details for some hotels can be found on our website

http://www.ago.ulg.ac.be/PeM/Coll/Liac39/

A couple of grants, including student dormitory accommodation, for young PhD students will be offered by the LOC. Students who wish to apply for a grant should submit the abstract of their contribution via the web- interface and send their application to: liac2010@misc.ulg.ac.be The application must reach us before 15 March 2010. We remind you that the proceedings of the conference will be published electronically as a special issue of the bulletin of the Lige Royal Scientific Society http://www.srsl-ulg.net/ which is an open-access, refereed publication. The template for the proceedings is available on our web site http://www.ago.ulg.ac.be/PeM/Coll/Liac39/ (link ”Proceedings”).

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.