THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar/planetary evolution and molecular clouds

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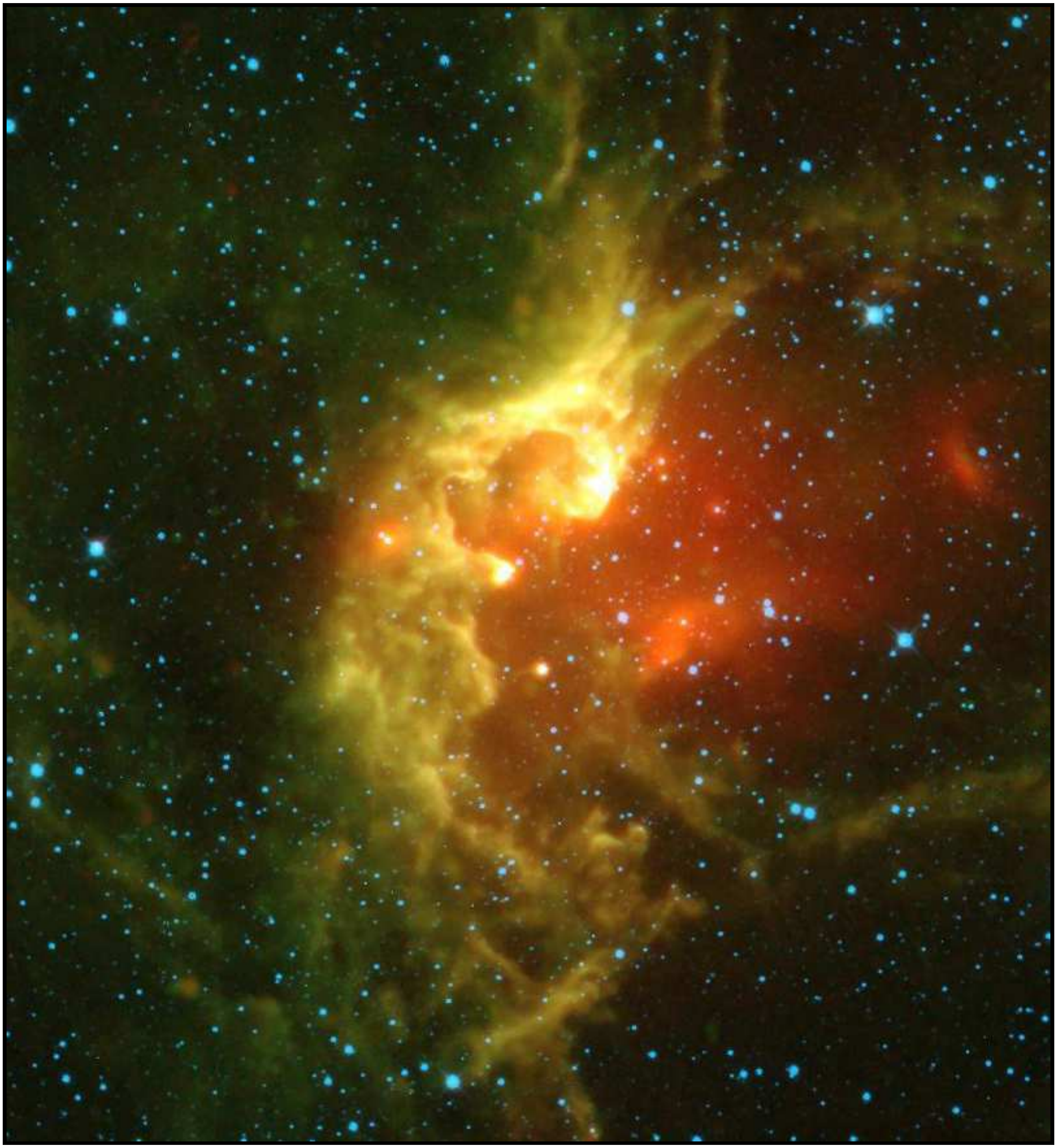

The Star Formation Newsletter

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star and planet 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). Additionally, the Newsletter brings short overview articles on objects of special interest, physical processes or theoretical results, the early solar system, as well as occasional interviews.

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Cover Picture

NGC 7380 is an open cluster located in Cepheus at a distance of approximately 2.2 kpc and with an age of about 5 Myr. The image is a mosaic from WISE data, and blue and cyan represent infrared light at 3.4 and 4.6 microns, which is primarily light from stars. Green and red represent light at 12 and 22 microns, which is primarily emission from warm dust. NGC 7380 was discovered by Caroline Herschel in 1787.

Image courtesy NASA/JPL-Caltech/UCLA.

Submitting your abstracts

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

Rafael Bachiller

in conversation with Bo Reipurth

Question: *What was the focus of your PhD and who was your adviser?*

Answer: Radioastronomy was essentially nonexistent in Spain when I graduated in Physics at the Madrid Complutense University in 1979. However, in Yebes, the National Astronomical Observatory (OAN) had installed a 13.7-m radiotelescope, a twin of the UMass telescope in Amherst, and IRAM was deciding to build the 30-m antenna at Pico Veleta, near Granada. In this context I was sent to France to learn the techniques of radioastronomy. Grenoble was the ideal place for this since IRAM was starting its activities there and Alain Omont had formed a small group at the University focussed on mm-wave astronomy: the CERMO, from which the Grenoble Observatory was later created. When I arrived in Grenoble, I worked under the supervision of Alain in a small but very lively group both at the scientific and human levels, with Claudine Kahane, Stephane Guilloteau, Robert Lucas and, somewhat later, Thierry Forveille and Gilles Duvert.

Q: *Some of your earliest work, together with José Cernicharo, dealt with the relation between carbon monoxide emission and visual extinction.*

A: Since my goal was to participate one day in the scientific exploitation of IRAM, Alain Omont decided to send me to Paris to collaborate with Michel Guélin and his student José Cernicharo. They were studying the CO/H_2 ratio in the Taurus clouds estimating H_2 from star counts and CO by using the mm-wave 2.5-m radiotelescope POM (*Petite Opération Millimétrique*) in Bordeaux. This was a kind of demonstrator of the mm-wave technologies which were needed for IRAM.

My project consisted in studying the CO/H_2 ratio in the PerOB2 molecular cloud complex. I needed to count stars on the Palomar Sky Survey plates to estimate the visual extinction to derive the H_2 column densities. To do so, I produced transparent grids with very small cells that I placed on the photographic image of the dark cloud and, with the help of a microscope, I counted the stars in every cell covering the full cloud as well as some reference fields free of extinction. It was a very boring task, and I had to spend many full days doing it. Fortunately, automatic machines were later developed to do this kind of work, and thanks to computers the extinction across the entire sky is now mapped to a great depth. Anyway, it is funny that I was initiated in astronomy looking through a microscope!

Later on, I was led to spend long periods at the Bordeaux Observatory observing the 1-0 line of CO at 115 GHz. These never were routine observations since knowing the telescope hardware and software, and interacting with it, was imperative to keep the experiment running.

One of the results from my thesis was that we observed differences in the CO/H_2 ratio between Perseus and Taurus, which we interpreted as caused by differences in the photodissociation levels. The stars in the Per OB2 association are an important source of ultraviolet radiation increasing the molecular photodissociation in the Perseus clouds. We published these results in 1986. Indeed knowing CO/H_2 was, and still is, of paramount importance to estimate the masses of molecular clouds in the Milky Way and in other galaxies from CO observations.

Q: *How did you become so interested in Perseus for such a long time?*

A: Beyond the CO/H_2 studies, my thesis gave me the possibility to know in great detail the Perseus clouds, a wonderful star-forming region that, in Michel Guélin's words, became 'my empire'. So after my Thèse d'État, I spent a very long time studying different aspects of these clouds trying to reveal their most interesting features. I carried out detailed studies of the fascinating HH 7-11 objects in NGC1333, the gas heated by Omicron Persei, the dense gas around the IC348 cluster, etc. I also identified some objects and regions which, with time, became very popular in the star formation community, such as Barnard 1, L1448, L1455, etc.

I also traveled around the world studying these regions with different radiotelescopes: the 20-m telescope in Onsala, the 100-m in Effelsberg, and then – in the US – the 13.7-m telescope at Amherst, the 140-ft in Green Bank and the Texas 5-m dish. It was a very instructive period, and I gained a lot of experience with radiotelescopes.

Q: *When did you return to Spain?*

A: I came back to Spain in 1986, just in time to participate in some of the first observations with the IRAM 30-m radiotelescope at Pico Veleta, which was officially inaugurated in September 1987. I joined the Observatorio Astronómico Nacional in Madrid in a permanent position, but I travelled very often to Granada, and to the Plateau de Bure to participate in the commissionning of the 3 x 15-m antennae interferometer of IRAM. Indeed I pointed the telescopes towards my favourite objects in Perseus as soon as I could. Some of the first observations at Pico Veleta were on IC348, which were published in 1987, and with the Plateau de Bure interferomenter we first observed L1448 in SiO, published in 1992.

As a result of all these observations, around 1990 I had been able to identify some of the young stellar objects which are, even today, among the youngest known protostars (such as L1448-mm, IRAS03282, L1448-IRS3, etc). These objects were grouped under the designation 'Class 0' by André et al. in 1993.

Q: *Back in 1990, you and your collaborators discovered a series of high-velocity bullets in the L1448 flow in Perseus.*

A: In the mean time, bipolar outflows had become a very popular topic in star formation research. I searched for outflows associated with the young protostars of Perseus and discovered that the bipolar outflows from Class 0 protostars were really extraordinary: very fast, very energetic, and highly collimated. Really similar to the HH jets that you, Bo, were studying around the same time in the optical. HH jets and CO outflows were considered somewhat different phenomena at that time, however both phenomena were clearly linked thanks to our observations. Indeed the CO outflow in L1448 (Bachiller et al. 1990, AA 231, 174) with its extremely high-velocity (EHV) bullets, so nicely symmetric both in position and velocity, soon became the prototype of such Class 0 outflows. With all these observations, instead of favoring models that assumed wide-angle winds, we established the paradigm of CO flows driven by highly collimated jets.

Q: *You have summarized what was known about molecular outflows in your highly cited Annual Reviews 1996 article. What are the main developments over the past 20 years?*

A: With all these results, during one of those beautiful summers that I used to spend in Grenoble, I wrote in 1996 the ARAA review paper formalizing the nomenclature of molecular bullets, EHV jets, etc. This review arrived 10 years after the review published by Charlie Lada in 1985, and it was amazing to see the big step made in the study of outflows in such a short period of time. This was mainly due to the arrival of IRAM and other mm-wave telescopes providing high angular resolution. Indeed the field has continued to progress during the last 20 years, with a big emphasis on high resolution studies and on the chemistry triggered by shocks. The interferometric images of the acceleration regions provided by NOEMA and ALMA are really captivating. The number of molecular species studied in shocks, and the chemical models to explain their evolution, progresses steadily. Nevertheless, in my opinion, the field has not progressed to such a high degree as in the previous 10 years.

Q: *From the 1990s on, you studied the unusual chemical abundances found in YSO outflows, first focussing on silicon monoxide.*

A: The next natural step was to study the chemistry of bipolar outflows. From the beginning we reported, in several papers, how special and distinctive SiO was. The SiO lines were only seen in shocks creating a spectacular observational effect. For instance, as we published in 1991, in the L1448 molecular bullets we found the SiO abundance to be enhanced by more than 4 orders of magnitude with respect to the gas in the ambient cloud. These and many more observations that we carried out implied that considerable amounts of gas-phase SiO were formed in the first evolutionary stages of bipolar outflows. SiO soon became a standard indicator of the extreme youth of an outflow, and one of the favourite topics of chemistry modelers.

Q: *You also discovered a methanol enhancement. Are these chemical peculiarities well understood now?*

A: Methanol had been considered until then just as one more molecule, perhaps peculiar because of its relatively complex structure and spectrum. Above all, methanol was then known because of its numerous and bright masers studied in detail by Malcolm Walmsley and Karl Menten. I was familiar with the methanol molecule because together with Karl Menten, and also with Russian colleagues, we had carried out several studies on its masers with the Yebes 13.7-m telescope.

However our data, now on L1157, revealed an exceptional behavior of the methanol *thermal lines* in shocks. I had the opportunity to discuss these results with the always enthusiastic Malcolm Walmsley, and in 1995 we published together a Letter reporting the methanol enhancement in shocks. I showed these results in one of the first Astrochemistry symposia, the one organized by Ewine van Dishoeck in Leiden in 1996, and we published another paper on the specific behaviour of methanol in 1998. We reported on observations of the NGC1333/IRAS2 jet and we carried out radiative transfer computations using the model developed by Malcolm. Claudio Codella was already working with us as a postdoctoral researcher at OAN, and became another methanol fan. Our results clearly revealed strong emission in the shocked molecular regions associated with shocks, while the emission from the quiescent material in the ambient dense core remained weak. The observed large methanol abundance enhancements (more than two orders of magnitude) were clearly caused by processes of desorption of grain mantles in shocks. Following this wealth of observations, methanol became quickly recognized as an essential ingredient in dust grain mantles.

Q: *You have devoted a substantial effort to study the outflow in L1157.*

A: Together with Mario Tafalla, in 1995 we had already identified the L1157 outflow as one of the most interesting outflows for chemical studies, and together with Miguel Pérez Gutiérrez, a Ph.D. student at the time, we carried out a spectral survey that allowed us to estimate the chemical enhancement of different molecular species in the high velocity gas associated with L1157.

These studies led to a very detailed work on L1157 in which we coined the term 'chemically active outflow' to describe this class of outflows that presents peculiar chemistry (Bachiller et al. 2001, AA 372, 899). It is impressive to see how this work has subsequently been extended and branched out, both from the point of view of observations and theory. Astrochemistry is, however, a very intricate discipline and many unknowns remain in the chemical shock processes.

Q: *In addition to your work on star formation, you have pursued studies of planetary nebulae.*

A: It was very tempting to compare the flows ejected by young stars to those ejected by evolved stars, there are many similarities indeed. So I started a program with Valentin Bujarrabal to observe at IRAM proto-planetary objects similar to CRL618. However, I soon became interested in Planetary Nebule (PNe): I found it amazing to find molecules in such harsh environments. The Ring Nebula in Lyra, NGC2346, and M2-9, were some of the objects I mapped in CO, and the results were published from 1989 on. The observations were very exciting, with the CO spacial distribution following or complementing the optical images of such bright nebulae. Patrick Huggins was also studying the molecular content of PNe at the New York University and we started a collaborative project to which Pierre Cox, Thierry Forveille, and Eric Josselin soon joined. Some of the PNe (e.g. the Helix or the Ring) were clearly made of small cometary globules of high density subjected to strong UV radiation from the central star: genuine mini-photodissociation regions! So the chemistry turned out to be very different from what we were observing in YSO outflows. I am very proud of the work we did together on the evolution of the molecular gas in PNe, I believe it still will take many years to be surpassed.

Q: *As director of the Observatorio Astronomico Nacional you have spent much time on administrative matters, and also been involved in outreach.*

A: In 2002 I was appointed director of OAN, at that time the Observatory was in charge of the construction of the 40-m radiotelescope in Yebes, was contributing Low Noise Amplifiers to Herschel, IRAM, and ALMA, and was involved in many more projects. From this position I became involved in numerous management tasks, both at the national and international levels. I was lucky enough to work with the VLBI community (thanks to our participation in the European VLBI Network), as well as with the SKA project groups. I had participated in the ALMA project from its very genesis in the 1990s; together with José Cernicharo and Jesús Martin-Pintado, we pushed hard for the involvement of Spain in such an exciting project. I contributed to the negotiation process that finally led to Spain joining ESO in 2006. From 2011 to 2016 I was designated Manager of the National Programme of Astronomy and Astrophysics, and my administrative tasks have not stopped increasing since then.

With regard to outreach, I should say that Astronomy is such a fascinating science that one (at least me) cannot refrain from telling others what is being discovered and studied. So I have always collaborated with mass media, and I was led to closely work with *El Mundo*, one of the two major Spanish newspapers, in which I have published around 300 articles, and in which, to further promote its content in science, I became a member of its Editorial Board.

Q: *What is the current focus of your research on star formation?*

A: Together with Bertrand Lefloch, we undertook, about 5 years ago, an ambitious project to study 'our chemical origins', i.e., the chemical evolution from pre-stellar cores to the formation of protostars, the bipolar outflows, the protoplanetary disks, and eventually the bodies of the planetary systems. Thanks to this project (ASAI: Astrochemical Surveys At IRAM) I have had the opportunity to return recently to the 30-m telescope to observe some of my well-known sources such as Barnard 1, L1448, SVS13, L1157, etc. The project is being extremely fruitful with sound contributions to the study of complex molecules (such as formamide, glycolaldehyde, or even cyanomethanimine!), phosphorous species, etc. As a very general result, we have realized that the molecular complexity in protoplanetary disks and in planetary system bodies is very likely linked to the rich chemistry already at work in the earliest stages of star formation. We have now published several papers with these results, and have just submitted a paper with the overall and global conclusions from the survey.

I keep collaborative programs with my colleagues at OAN, mainly Mario Tafalla and Asunción Fuente, on outflows and on the structure of protoplanetary disks. I also continue working with Nanda Kumar (now in Porto), and with Claudio Codella (now in Firenze), who were working with me as postdoctoral researchers a long time ago. The images we are obtaining of the outflow acceleration regions with ALMA are really amazing.

Abstracts of recently accepted papers

On the star-forming ability of Molecular Clouds

S. Anathpindika[1], A. Burkert[2] and R. Kuiper[3]

[1] Indian Institute of Technology, Kharagpur, India
[2] University Observatory Munich, Schneirstrasse 1, D-81679, Munich, Germany
[3] Institute of Astronomy and Astrophysics, University of Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen, Germany

E-mail contact: sumed_k *at* yahoo.co.in

The star-forming ability of a molecular cloud depends on the fraction of gas it can cycle into the dense-phase. Consequently, one of the crucial questions in reconciling star-formation in clouds is to understand the factors that control this process. While it is widely accepted that the variation in ambient conditions can alter significantly the ability of a cloud to spawn stars, the observed variation in the star-formation rate in nearby clouds that experience similar ambient conditions, presents an interesting question. In this work we attempted to reconcile this variation within the paradigm of colliding flows. To this end we develop self-gravitating, hydrodynamic realisations of identical flows, but allowed to collide off-centre. Typical observational diagnostics such as the gas-velocity dispersion, the fraction of dense-gas, the column density distribution (N-PDF), the distribution of gas mass as a function of K-band extinction and the strength of compressional/solenoidal modes in the post-collision cloud were deduced for different choices of the impact parameter of collision. We find that a strongly sheared cloud is terribly inefficient in cycling gas into the dense phase and that such a cloud can possibly reconcile the sluggish nature of star-formation reported for some clouds. Within the paradigm of cloud-formation via colliding flows this is possible in case of flows colliding with a relatively large impact parameter. We conclude that compressional modes - though probably essential - are insufficient to ensure a relatively higher star-formation efficiency in a cloud.

Accepted by Monthly Notices of the Royal Astronomical Society

https://arxiv.org/pdf/1710.07479

The stellar content of the infalling molecular clump G286.21+0.17

M. Andersen[1], P.J. Barnes[2,3], J.C. Tan[2], J. Kainulainen[4] and G. deMarchi[5]

[1] Gemini Observatory, Casilla 603, La Serena, Chile
[2] Department of Astronomy, University of Florida, Gainesville, FL 32611, USA
[3] School of Science and Technology, University of New England, Armidale NSW 2351, Australia
[4] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
[5] Research & Scientific Support Department, ESA ESTEC, Keplerlaan 1, 2200 AG Noordwijk, The Netherlands

E-mail contact: manderse *at* gemini.edu

The early evolution during massive star cluster formation is still uncertain. Observing embedded clusters at their earliest stages of formation can provide insight into the spatial and temporal distribution of the stars and thus probe different star cluster formation models. We present near-infrared imaging of an 8'*13'(5.4pc*8.7pc) region around the massive infalling clump G286.21+0.17(also known as BYF73). The stellar content across the field is determined and photometry is derived in order to obtain stellar parameters for the cluster members. We find evidence for some sub-structure (on scales less than a pc diameter) within the region with apparently at least three different sub-clusters associated with the molecular clump based on differences in extinction and disk fractions. At the center of the clump we identify a deeply embedded sub-cluster. Near-infrared excess is detected for 39-44sub-clusters associated with molecular material and 27% for the exposed cluster. Using the disk excess as a proxy for age this suggests the clusters are very young. The current total stellar mass is estimated to be at least 200 Msun. The molecular core hosts a rich population of pre-main sequence stars. There is evidence for multiple events of star formation both in terms of the

spatial distribution within the star forming region and possibly from the disk frequency.

Accepted by ApJ

https://arxiv.org/pdf/1709.10448

ALMA Observations of SMM11 Reveal an Extremely Young Protostar in Serpens Main Cluster

Yusuke Aso[1,2], Nagayoshi Ohashi[1,2], Yuri Aikawa[3], Masahiro N. Machida[4], Kazuya Saigo[5], Masao Saito[6,7], Shigehisa Takakuwa[8,1], Kengo Tomida[9], Kohji Tomisaka[10], Hsi-Wei Yen[11] and Jonathan P. Williams[12]

[1] Academia Sinica Institute of Astronomy and Astrophysics/P.O. Box 23-141, Taipei 106, Taiwan
[2] Subaru Telescope, National Astronomical Observatory of Japan/650 North Aohoku Place, Hilo, HI 96720, USA
[3] Department of Astronomy, Graduate School of Science, The University of Tokyo/7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[4] Department of Earth and Planetary Sciences, Faculty of Sciences Kyushu University/Fukuoka 812-8581, Japan
[5] Chile Observatory, National Astronomical Observatory of Japan/Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan
[6] Nobeyama Radio Observatory/Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan
[7] SOKENDAI, Department of Astronomical Science, Graduate University for Advanced Studies, Japan
[8] Department of Physics and Astronomy, Graduate School of Science and Engineering, Kagoshima University/1-21-35 Korimoto, Kagoshima, Kagoshima 890-0065, Japan
[9] Department of Earth and Space Science, Osaka University/Toyonaka, Osaka 560-0043, Japan
[10] National Astronomical Observatory of Japan/Osawa, 2-21-1, Mitaka, Tokyo 181-8588, Japan
[11] European Southern Observatory/Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany
[12] Institute for Astronomy, University of Hawaii at Manoa/Honolulu, Hawaii, USA

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

We report the discovery of an extremely young protostar, SMM11, located in the associated submillimeter condensation in the Serpens Main cluster using the Atacama Large Millimeter/submillimeter Array (ALMA) during its Cycle 3 at 1.3 mm and an angular resolution of $\sim 0\farcs5 \sim 210$ AU. SMM11 is a Class 0 protostar without any counterpart at 70 μm or shorter wavelengths. The ALMA observations show 1.3 mm continuum emission associated with a collimated ^{12}CO bipolar outflow. *Spitzer* and *Herschel* data show that SMM11 is extremely cold ($T_{\rm bol}$ =26 K) and faint ($L_{\rm bol} \lesssim 0.9\ L_{\odot}$). We estimate the inclination angle of the outflow to be $\sim 80^{\circ}$, almost parallel to the plane of the sky, from simple fitting using wind-driven-shell model. The continuum visibilities consist of Gaussian and power-law components, suggesting a spherical envelope with a radius of ~ 600 AU around the protostar. The estimated low $C^{18}O$ abundance, $X(C^{18}O)$=1.5-3$\times10^{-10}$, is also consistent with its youth. The high outflow velocity, a few 10 km s^{-1} at a few 1000 AU, is much higher than theoretical simulations of first hydrostatic cores and we suggest that SMM11 is a transitional object right after the second collapse of the first core.

Accepted by The Astrophysical Journal Letters

https://arxiv.org/pdf/1710.10787

The Effect of Magnetic Fields and Ambipolar Diffusion on the Column Density Probability Distribution Function in Molecular Clouds

Sayantan Auddy[1,2], Shantanu Basu[1] and Takahiro Kudoh[3]

[1] Department of Physics and Astronomy, The University of Western Ontario, London, ON N6A 3K7, Canada
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[3] Faculty of Education, Nagasaki University, 1-14 Bunkya-manchi, Nagasaki 852-8521, Japan

E-mail contact: sauddy3 *at* uwo.ca

Simulations generally show that non-self-gravitating clouds have a lognormal column density (Σ) probability distribution function (PDF), while self-gravitating clouds with active star formation develop a distinct power-law tail at high column density. Although the growth of the power law can be attributed to gravitational contraction leading to the formation of condensed cores, it is often debated if an observed lognormal shape is a direct consequence of supersonic turbulence alone, or even if it is really observed in molecular clouds. In this paper we run three-dimensional magnetohydrodynamic simulations including ambipolar diffusion with different initial conditions to see the effect of strong magnetic fields and nonlinear initial velocity perturbations on the evolution of the column density PDFs. Our simulations show that column density PDFs of clouds with supercritical mass-to-flux ratio, with either linear perturbations or nonlinear turbulence, quickly develop a power-law tail such that $dN/d\log\Sigma \propto \Sigma^{-\alpha}$ with index $\alpha \simeq 2$. Interestingly, clouds with subcritical mass-to-flux ratio also proceed directly to a power-law PDF, but with a much steeper index $\alpha \simeq 4$. This is a result of gravitationally-driven ambipolar diffusion. However, for nonlinear perturbations with a turbulent spectrum ($v_k^2 \propto k^{-4}$), the column density PDFs of subcritical clouds do retain a lognormal shape for a major part of the cloud evolution, and only develop a distinct power-law tail with index $\alpha \simeq 2$ at greater column density when supercritical pockets are formed.

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Large Interstellar Polarisation Survey. LIPS I: FORS2 spectropolarimetry in the Southern Hemisphere

S. Bagnulo[1], N.L.J. Cox[2], A. Cikota[3], R. Siebenmorgen[3], N.V. Voshchinnikov[4], F. Patat[3], K.T. Smith[5], J.V. Smoker[6], S. Taubenberger[3,7], L. Kaper[2] and J. Cami[8]

[1] Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, Northern Ireland, U.K.
[2] Anton Pannekoek Institute for Astronomy, University of Amsterdam, NL-1090 GE Amsterdam, The Netherlands
[3] European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching b. Muenchen, Germany
[4] Sobolev Astronomical Institute, St. Petersburg University, Universitetskii prosp. 28, St. Petersburg, 198504 Russia
[5] AAAS Science International, Clarendon House, Clarendon Road, Cambridge CB2 8FH, UK
[6] European Southern Observatory, Alonso de Cordova 3107, Casilla 19001, Vitacura, Santiago 19, Chile
[7] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85741 Garching b. Muenchen, Germany
[8] Department of Physics and Astronomy and Centre for Planetary, Science and Exploration (CPSX), The University of Western Ontario, London, ON N6A 3K7, Canada

E-mail contact: sba *at* arm.ac.uk

Polarimetric studies of light transmitted through interstellar clouds may give constraints on the properties of the interstellar dust grains. Traditionally, broadband linear polarisation (BBLP) measurements have been considered an important diagnostic tool for the study of the interstellar dust, while comparatively less attention has been paid to spectropolarimetric measurements. However, spectropolarimetry may offer stronger constraints than BBLP, for example by revealing narrowband features, and by allowing us to distinguish the contribution of dust from the contribution of interstellar gas. Therefore, we have decided to carry out a Large Interstellar Polarisation Survey (LIPS) using spectropolarimetric facilities in both hemispheres. Here we present the results obtained in the Southern Hemisphere with the FORS2 instrument of the ESO Very Large Telescope. Our spectra cover the wavelength range 380–950 nm at a spectral resolving power of about 880. We have produced a publicly available catalogue of 127 linear polarisation spectra of 101 targets. We also provide the Serkowski-curve parameters, as well as the wavelength gradient of the polarisation position angle for the interstellar polarisation along 76 different lines of sight. In agreement with previous literature, we found that the best-fit parameters of the Serkowski-curve are not independent of each other. However, the relationships that we obtained are not always consistent with what has been found in previous studies.

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http://arxiv.org/pdf/1710.02439

GMC Collisions as Triggers of Star Formation. V. Observational Signatures

Thomas G. Bisbas[1,2], Kei E. I. Tanaka[1], Jonathan C. Tan[1,3,4], Benjamin Wu[4] and Fumitaka Nakamura[4]

[1] Department of Astronomy, University of Florida, Gainesville, FL 32611, USA
[2] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, D-85748 Garching, Germany
[3] Department of Physics, University of Florida, Gainesville, FL 32611, USA
[4] National Astronomical Observatory of Japan, Mitaka, Tokyo, 181-8588, Japan

E-mail contact: tbisbas *at* ufl.edu

We present calculations of molecular, atomic and ionic line emission from simulations of giant molecular cloud (GMC) collisions. We post-process snapshots of the magneto-hydrodynamical simulations presented in an earlier paper in this series by Wu et al. (2017a) of colliding and non-colliding GMCs. Using photodissociation region (PDR) chemistry and radiative transfer we calculate the level populations and emission properties of ^{12}CO $J = 1-0$, [CI] $^3P_1 \rightarrow {}^3P_0$ at 609 μm, [CII] 158 μm and [OI] $^3P_1 \rightarrow {}^3P_0$ transition at 63 μm. From integrated intensity emission maps and position-velocity diagrams, we find that fine-structure lines, particularly the [CII] 158 μm, can be used as a diagnostic tracer for cloud-cloud collision activity. These results hold even in more evolved systems in which the collision signature in molecular lines has been diminished.

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On the Origin of Banded Structure in Dusty Protoplanetary Discs: HL Tau and TW Hya

A.C. Boley[1]

[1] Department of Physics and Astronomy, University of British Columbia, Vancouver BC, Canada

E-mail contact: aaron.boley *at* gmail.com

Recent observations of HL Tau revealed remarkably detailed structure within the system's circumstellar disc. A range of hypotheses have been proposed to explain the morphology, including, e.g., planet-disc interactions, condensation fronts, and secular gravitational instabilities. While embedded planets seem to be able to explain some of the major structure in the disc through interactions with gas and dust, the substructure, such as low-contrast rings and bands, are not so easily reproduced. Here, we show that dynamical interactions between three planets (only two of which are modelled) and an initial population of large planetesimals can potentially explain both the major and minor banded features within the system. In this context, the small grains, which are coupled to the gas and reveal the disc morphology, are produced by the collisional evolution of the newly-formed planetesimals, which are ubiquitous in the system and are decoupled from the gas.

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Clustering the Orion B giant molecular cloud based on its molecular emission

Emeric Bron[1,2], Chloé Daudon[3], Jérôme Pety[4,3], François Levrier[3], Maryvonne Gerin[3], Pierre Gratier[5], Jan H. Orkisz[6,4,3], Viviana Guzman[7], Sébastien Bardeau[4], Javier R. Goicoechea[1], Harvey Liszt[8], Karin Öberg[9], Nicolas Peretto[10], Albrecht Sievers[4], and Pascal Tremblin[11]

[1] ICMM, Consejo Superior de Investigaciones Cientificas (CSIC). E-28049. Madrid, Spain
[2] LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, 92190 Meudon, France
[3] LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, École normale supérieure, 75005 Paris, France
[4] IRAM, 300 rue de la Piscine, 38406 Saint Martin d'Hères, France
[5] Laboratoire d'astrophysique de Bordeaux, Univ. Bordeaux, CNRS, B18N, allée Geoffroy Saint-Hilaire, 33615 Pessac, France
[6] Univ. Grenoble Alpes, IRAM, 38000 Grenoble, France
[7] Joint ALMA Observatory (JAO), Alonso de Cordova 3107 Vitacura, Santiago de Chile, Chile
[8] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA, 22903, USA
[9] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA, 02138, USA
[10] School of Physics and Astronomy, Cardiff University, Queen's buildings, Cardiff CF24 3AA, UK
[11] Maison de la Simulation, CEA-CNRS-INRIA-UPS-UVSQ, USR 3441, Centre d'étude de Saclay, F-91191 Gif-Sur-Yvette, France

E-mail contact: emeric.bron *at* obspm.fr

Previous attempts at segmenting molecular line maps of molecular clouds have focused on using position-position-velocity data cubes of a single line to separate the spatial components of the cloud. In contrast, wide field spectral imaging with large spectral bandwidth in the (sub)mm domain now allows to combine multiple molecular tracers to understand the different physical and chemical phases that constitute giant molecular clouds. We aim at using multiple tracers (sensitive to different physical processes) to segment a molecular cloud into physically/chemically similar regions (rather than spatially connected components). We use a machine learning clustering method (the Meanshift algorithm) to cluster pixels with similar molecular emission, ignoring spatial information. Simple radiative transfer models are used to interpret the astrophysical information uncovered by the clustering. A clustering analysis based only on the J=1–0 lines of ^{12}CO, ^{13}CO and C^{18}O reveals distinct density/column density regimes ($n_{\rm H} \sim 100$, 500, and >1000 cm^{-3}), closely related to the usual definitions of diffuse, translucent and high-column-density regions. Adding two UV-sensitive tracers, the (1=-0) lines of HCO$^+$ and CN, allows us to distinguish two clearly distinct chemical regimes, characteristic of UV-illuminated and UV-shielded gas. The UV-illuminated regime shows overbright HCO$^+$ and CN emission, which we relate to photochemical enrichment. We also find a tail of high CN/HCO$^+$ intensity ratio in UV-illuminated regions. Finer distinctions in density classes ($n_{\rm H} \sim 7\times10^3$, and 4×10^4 cm^{-3}) for the densest regions are also identified, likely related to the higher critical density of the CN and HCO$^+$ (1–0) lines. The association of simultaneous multi-line, wide-field mapping and powerful machine learning methods such as the Meanshift algorithm reveals how to decode the complex information available in molecular tracers.

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Transfer, loss and physical processing of water in hit-and-run collisions of planetary embryos

C. Burger[1], T.I. Maindl[1], C.M. Schäfer[2]

[1] Department of Astrophysics, University of Vienna, Türkenschanzstraße 17, 1180 Vienna

[2] Institut für Astronomie und Astrophysik, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen

E-mail contact: c.burger *at* univie.ac.at

Collisions between large, similar-sized bodies are believed to shape the final characteristics and composition of terrestrial planets. Their inventories of volatiles such as water, are either delivered or at least significantly modified by such events. Besides the transition from accretion to erosion with increasing impact velocity, similar-sized collisions can also result in hit-and-run outcomes for sufficiently oblique impact angles and large enough projectile-to-target mass ratios. We study volatile transfer and loss focusing on hit-and-run encounters by means of Smooth Particle Hydrodynamics simulations, including all main parameters: impact velocity, impact angle, mass ratio, and also the total colliding mass. We find a broad range of overall water losses, up to 75% in the most energetic hit-and-run events, and confirm the much more severe consequences for the smaller body also for stripping of volatile layers. Transfer of water between projectile and target inventories is found to be mostly rather inefficient, and final water contents are dominated by pre-collision inventories reduced by impact losses, for similar pre-collision water mass fractions. Comparison with our numerical results shows that current collision outcome models are not accurate enough to reliably predict these composition changes in hit-and-run events. To also account for non-mechanical losses we estimate the amount of collisionally vaporized water over a broad range of masses, and find that these contributions are particularly important in collisions of ∼Mars-sized bodies, with sufficiently high impact energies, but still relatively low gravity. Our results clearly indicate that the cumulative effect of several (hit-and-run) collisions can efficiently strip protoplanets of their volatile layers, especially the smaller body, as it might be common e.g. for Earth-mass planets in systems with Super-Earths.

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DZ Cha: a bona fide photoevaporating disc

H. Canovas[1,2], B. Montesinos[3], M.R. Schreiber[4,11,12], L.A. Cieza[5,11], C. Eiroa[1], G. Meeus[1], J. de Boer[6], F. Ménard[7], Z. Wahhaj[8], P. Riviere-Marichalar[9], J. Olofsson[4,12], A. Garufi[1], I. Rebollido[1], R.G. van Holstein[6], C. Caceres[10,11,12], A. Hardy[4,11], E. Villaver[1]

[1] Departamento de Física Teórica, Universidad Autónoma de Madrid, Cantoblanco, 28049, Madrid, Spain
[2] European Space Astronomy Centre (ESA), Camino Bajo del Castillo s/n, 28692, Villanueva de la Cañada, Madrid, Spain
[3] Dept. of Astrophysics, Centre for Astrobiology (CAB, CSIC-INTA), ESAC Campus, Camino Bajo del Castillo s/n, 28692 Villanueva de la Cañada, Madrid, Spain
[4] Departamento de Fsica y Astronomía, Universidad de Valparaso, Valparaíso, Chile
[5] Facultad de Ingeniería y Ciencias, Universidad Diego Portales, Av. Ejercito 441, Santiago, Chile
[6] Leiden Observatory, Leiden University, P.O. Box 9513,2300RA Leiden, The Netherlands
[7] Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France
[8] European Southern Observatory, 3107 Alonso de Cordova, Vitacura, 1058 Santiago, Chile
[9] Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC). E-28049, Cantoblanco, Madrid, Spain
[10] Departamento de Ciencias Fisicas, Facultad de Ciencias Exactas, Universidad Andres Bello. Av. Fernandez Concha 700, Las Condes, Santiago, Chile
[11] Millennium Nucleus "Protoplanetary discs in ALMA Early Science"
[12] Millennium Nucleus for Planet Formation

E-mail contact: hcanovas *at* sciops.esa.int

DZ Cha is a weak-lined T Tauri star (WTTS) surrounded by a bright protoplanetary disc with evidence of inner disc clearing. Its narrow Hα line and infrared spectral energy distribution suggest that DZ Cha may be a photoevaporating disc. We aim to analyse the DZ Cha star + disc system to identify the mechanism driving the evolution of this object. We have analysed three epochs of high resolution optical spectroscopy, photometry from the UV up to the sub-mm regime, infrared spectroscopy, and J-band imaging polarimetry observations of DZ Cha. Combining our analysis with previous studies we find no signatures of accretion in the Hα line profile in nine epochs covering a time baseline of $\sim$20 years. The optical spectra are dominated by chromospheric emission lines, but they also show emission from the forbidden lines [SII] 4068 and [OI] 6300 $\AA$ that indicate a disc outflow. The polarized images reveal a dust depleted cavity of $\sim$7 au in radius and two spiral-like features, and we derive a disc dust mass limit of $M_{\rm dust} < 3\ M_{\oplus}$ from the sub-mm photometry. No stellar ($M_{\odot} > 80 M_{\rm Jup}$) companions are detected down to 0.″ ($\sim$8 au, projected). The negligible accretion rate, small cavity, and forbidden line emission strongly suggests that DZ Cha is currently at the initial stages of disc clearing by photoevaporation. At this point the inner disc has drained and the inner wall of the truncated outer disc is directly exposed to the stellar radiation. We argue that other mechanisms like planet formation or binarity cannot explain the observed properties of DZ Cha. The scarcity of objects like this one is in line with the dispersal timescale ($\lesssim 10^5$ yr) predicted by this theory. DZ Cha is therefore an ideal target to study the initial stages of photoevaporation.

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A study of dust properties in the inner sub-au region of the Herbig Ae star HD 169142 with VLTI/PIONIER

L. Chen[1], Á. Kóspál[1,2], P. Ábrahám[1], A. Kreplin[3], A. Matter[4] and G. Weigelt[5]

[1] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Konkoly Thege Miklós út 15-17, 1121 Budapest, Hungary
[2] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
[3] University of Exeter, Department of Physics and Astronomy, Stocker Road, Exeter, Devon EX4 4QL, UK
[4] Laboratoire Lagrange, Université Cóte d'Azur, Observatoire de la Cóte d'Azur, CNRS, Boulevard de l'Observatoire, CS 34229, 06304 Nice Cedex 4, France
[5] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

E-mail contact: lei.chen *at* csfk.mta.hu

An essential step to understanding protoplanetary evolution is the study of disks that contain gaps or inner holes. The pre-transitional disk around the Herbig star HD 169142 exhibits multi-gap disk structure, differentiated gas and dust distribution, planet candidates, and near-infrared fading in the past decades, which make it a valuable target for a case study of disk evolution. Using near-infrared interferometric observations with VLTI/PIONIER, we aim to study the dust properties in the inner sub-au region of the disk in the years 2011-2013, when the object is already in its near-infrared faint state. We first performed simple geometric modeling to characterize the size and shape of the NIR-emitting region. We then performed Monte-Carlo radiative transfer simulations on grids of models and compared the model predictions with the interferometric and photometric observations. We find that the observations are consistent with optically thin gray dust lying at $R_{\rm in} \sim 0.07$ au, passively heated to $T \sim 1500$ K. Models with sub-micron optically thin dust are excluded because such dust will be heated to much higher temperatures at similar distance. The observations can also be reproduced with a model consisting of optically thick dust at $R_{\rm in} \sim 0.06$ au, but this model is plausible only if refractory dust species enduring ∼2400 K exist in the inner disk.

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Precessing Jet and Large Dust Grains in the V380 Ori NE Star-forming Region

Minho Choi[1], Miju Kang[1], Jeong-Eun Lee[2], Ken'ichi Tatematsu[3,4], Sung-Ju Kang[1], Jack Sayers[5], Neal J. Evans II[1,6], Jungyeon Cho[7], Jungmi Kwon[8], Geumsook Park[1,7,9], Satoshi Ohashi[10], Hyunju Yoo[2,7] and Youngung Lee[1]

[1] Korea Astronomy and Space Science Institute
[2] School of Space Research, Kyung Hee University
[3] National Astronomical Observatory of Japan
[4] Department of Astronomical Science, SOKENDAI (The Graduate University for Advanced Studies)
[5] Department of Physics, Math, and Astronomy, California Institute of Technology
[6] Department of Astronomy, University of Texas at Austin
[7] Department of Astronomy and Space Science, Chungnam National University
[8] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency
[9] Department of Physics and Astronomy, Seoul National University
[10] The Institute of Physical and Chemical Research (RIKEN)

E-mail contact: minho *at* kasi.re.kr

The V380 Ori NE bipolar outflow was imaged in the SiO and CO J = 1 - 0 lines, and dense cores in L1641 were observed in the 2.0-0.89 mm continuum. The highly collimated SiO jet shows point-symmetric oscillation patterns in both position and velocity, which suggests that the jet axis is precessing and the driving source may belong to a non-coplanar binary system. By considering the position and velocity variabilities together, accurate jet parameters were derived. The protostellar system is viewed nearly edge-on, and the jet has a flow speed of 35 km/s and a precession period of 1600 years. The CO outflow length gives a dynamical timescale of 6300 years, and the protostar must be extremely young. The inferred binary separation of 6-70 au implies that this protobinary system may have been formed through the disk instability process. The continuum spectra of L1641 dense cores indicate that the emission comes from dust, and the fits with modified blackbody functions give emissivity power indices of beta = 0.3-2.2. The emissivity index shows a positive correlation with the molecular line width, but no strong correlation with bolometric luminosity or temperature. V380 Ori NE has a particularly low value of beta = 0.3, which tentatively suggests the presence of millimeter-sized dust grains. Because the dust growth takes millions of years, much longer than the protostellar age, this core may have produced large grains in the starless core stage. HH 34 MMS and HH 147 MMS also have low emissivity indices.

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Deep K-band observations of TMC-1 with the Green Bank Telescope: Detection of HC_7O, non-detection of $HC_{11}N$, and a search for new organic molecules

M.A. Cordiner[1,2], S.B. Charnley[1], Z. Kisiel[3], B.A. McGuire[4], Y.-J. Kuan[5,6]

[1] Astrochemistry Laboratory and the Goddard Center for Astrobiology, NASA Goddard Space Flight Center, 8800 Greenbelt Road, MD 20771, USA
[2] Institute for Astrophysics and Computational Sciences, The Catholic University of America, Washington, DC 20064, USA

[3] Institute of Physics, Polish Academy of Sciences, Al. Lotnikow 32/46, 02-668 Warszawa, Poland
[4] National Radio Astronomy Observatory, Charlottesville, VA 22903, USA
[5] National Taiwan Normal University, Taipei 116, Taiwan, ROC
[6] Institute of Astronomy and Astrophysics, Academia Sinica, Taipei 106, Taiwan, ROC

E-mail contact: martin.cordiner *at* nasa.gov

The 100 m Robert C. Byrd Green Bank Telescope K-band (KFPA) receiver was used to perform a high-sensitivity search for rotational emission lines from complex organic molecules in the cold interstellar medium towards TMC-1 (cyanopolyyne peak), focussing on the identification of new carbon-chain-bearing species as well as molecules of possible prebiotic relevance. We report a detection of the carbon-chain oxide species HC_7O and derive a column density of $(7.8\pm0.9) \times 10^{11}$ cm^{-2}. This species is theorized to form as a result of associative electron detachment reactions between oxygen atoms and C_7H^-, and/or reaction of $C_6H_2{}^+$ with CO (followed by dissociative electron recombination). Upper limits are given for the related HC_6O, C_6O and C_7O molecules. In addition, we obtained the first detections of emission from individual ^{13}C isotopologues of HC_7N, and derive abundance ratios $HC_7N/HCCC^{13}CCCCN = 110\pm16$ and $HC_7N/HCCCC^{13}CCCN = 96\pm11$, indicative of significant ^{13}C depletion in this species relative to the local interstellar elemental $^{12}C/^{13}C$ ratio of 60–70. The observed spectral region covered two transitions of $HC_{11}N$, but emission from this species was not detected, and the corresponding column density upper limit is 7.4×10^{10} cm^{-2} (at 95% confidence). This is significantly lower than the value of 2.8×10^{11} cm^{-2} previously claimed by Bell et al. (1997) and confirms the recent non-detection of $HC_{11}N$ in TMC-1 by Loomis et al. (2016). Upper limits were also obtained for the column densities of malononitrile and the nitrogen heterocycles quinoline, isoquinoline and pyrimidine.

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New Parallaxes for the Upper Scorpius OB Association

J.K. Donaldson[1], A.J. Weinberger[1], J. Gagné[1,2], A.P. Boss[1], S.A. Keiser[1]

[1] Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Rd NW, Washington, DC 20015, USA
[2] NASA Sagan Fellow

E-mail contact: jdonaldson *at* carnegiescience.edu

Upper Scorpius is a subgroup of the nearest OB association, Scorpius–Centaurus. Its young age makes it an important association to study star and planet formation. We present parallaxes to 52 low mass stars in Upper Scorpius, 28 of which have full kinematics. We measure ages of the individual stars by combining our measured parallaxes with pre-main sequence evolutionary tracks. We find there is a significant difference in the ages of stars with and without circumstellar disks. The stars without disks have a mean age of 4.9±0.8 Myr and those with disks have an older mean age of 8.2±0.9 Myr. This somewhat counterintuitive result suggests that evolutionary effects in young stars can dominate their apparent ages. We also attempt to use the 28 stars with full kinematics (i.e. proper motion, radial velocity, and parallax) to trace the stars back in time to their original birthplace to obtain a trackback age. We find, as expected given large measurement uncertainties on available radial velocity measurements, that measurement uncertainties alone cause the group to diverge after a few Myr.

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Planetesimal formation starts at the snow line

J. Drazkowska[1] and Y. Alibert[2]

[1] Institute for Computational Science, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[2] Physikalisches Institut & Center for Space and Habitability, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland

E-mail contact: joannad *at* physik.uzh.ch

Planetesimal formation stage represents a major gap in our understanding of the planet formation process. The late-stage planet accretion models typically make arbitrary assumptions about planetesimals and pebbles distribution while the dust evolution models predict that planetesimal formation is only possible at some orbital distances. We want to test the importance of water snow line for triggering formation of the first planetesimals during the gas-rich phase of protoplanetary disk, when cores of giant planets have to form. We connect prescriptions for gas disk evolution, dust growth and fragmentation, water ice evaporation and recondensation, as well as transport of both solids and water vapor, and planetesimal formation via streaming instability into a single, one-dimensional model for protoplanetary disk evolution. We find that processes taking place around the snow line facilitate planetesimal formation in two ways. First, due to the change of sticking properties between wet and dry aggregates, there is a "traffic jam" inside of the snow line that slows down the fall of solids onto the star. Second, ice evaporation and outward diffusion of water followed by its recondensation increases the abundance of icy pebbles that trigger planetesimal formation via streaming instability just outside of the snow line. Planetesimal formation is hindered by growth barriers and radial drift and thus requires particular conditions to take place. Snow line is a favorable location where planetesimal formation is possible for a wide range of conditions, but still not in every protoplanetary disk model. This process is particularly promoted in large, cool disks with low intrinsic turbulence and increased initial dust-to-gas ratio.

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Accreting Transition Discs with large cavities created by X-ray photoevaporation in C and O depleted discs

Barbara Ercolano[1,2], Michael L. Weber[1], James E. Owen[3]

[1] Universitäts-Sternwarte München, Scheinerstr. 1, 81679 München, Germany

[2] Excellence Cluster Origin and Structure of the Universe, Boltzmannstr.2, 85748 Garching bei München, Germany

[3] Astrophysics Group, Imperial College London, Blackett Laboratory, Prince Consort Road, London SW7 2AZ, UK

E-mail contact: ercolano *at* usm.lmu.de

Circumstellar discs with large dust depleted cavities and vigorous accretion onto the central star are often considered signposts for (multiple) giant planet formation. In this letter we show that X-ray photoevaporation operating in discs with modest (factors 3–10) gas-phase depletion of Carbon and Oxygen at large radii (>15 AU) yield the inner radius and accretion rates for most of the observed discs, without the need to invoke giant planet formation. We present one-dimensional viscous evolution models of discs affected by X-ray photoevaporation assuming moderate gas-phase depletion of Carbon and Oxygen, well within the range reported by recent observations. Our models use a simplified prescription for scaling the X-ray photoevaporation rates and profiles at different metallicity, and our quantitative result depends on this scaling. While more rigorous hydrodynamical modelling of mass loss profiles at low metallicities is required to constrain the observational parameter space that can be explained by our models, the general conclusion that metal sequestering at large radii may be responsible for the observed diversity of transition discs is shown to be robust. Gap opening by giant planet formation may still be responsible for a number of observed transition discs with large cavities and very high accretion rate.

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Understanding the links among magnetic fields, filament, the bipolar bubble, and star formation in RCW57A using NIR polarimetry

Chakali Eswaraiah[1,2,3], Shih-Ping Lai[1], Wen-Ping Chen[2], A.K. Pandey[3], M. Tamura[4,5], G. Maheswar[3], S. Sharma[3], Jia-Wei Wang[1], S. Nishiyama[6], Y. Nakajima[7], Jungmi Kwon[8], R. Purcell[9], and A.M. Magalhães[10]

[1] Institute of Astronomy, National Tsing Hua University, 101 Section 2, Kuang Fu Road, Hsinchu 30013, Taiwan

[2] Institute of Astronomy, National Central University, 300 Jhongda Rd, Jhongli, Taoyuan Country 32054, Taiwan

[3] Aryabhatta Research Institute of Observational Sciences (ARIES), Manora-peak, Nainital, Uttarakhandstate, 263002, India

[4] Department of Astronomy, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo

113-0033, Japan
[5] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[6] Miyagi University of Education, 149 Aramaki–aza–Aoba, Aobaku, Sendai, Miyagi 980-0845, Japan
[7] Center of Information and Communication Technology, Hitotsubashi University, 2-1 Naka, Kunitachi, Tokyo 186-8601, Japan
[8] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yohinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan
[9] Sydney Institute for Astronomy (SIfA), School of Physics, The University of Sydney, NSW 2006, Australia
[10] Inst. de Astronomia, Geofisica & Ciencias Atmosfericas, Univ. de Sao Paulo, Sao Paulo, Brazil

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

The influence of magnetic fields (B-fields) in the formation and evolution of bipolar bubbles, due to the expanding ionization fronts (I-fronts) driven by the HII regions that are formed and embedded in filamentary molecular clouds, has not been well-studied yet. In addition to the anisotropic expansion of I-fronts into a filament, B-fields are expected to introduce an additional anisotropic pressure which might favor expansion and propagation of I-fronts to form a bipolar bubble. We present results based on near-infrared polarimetric observations towards the central $\sim 8' \times 8'$ area of the star-forming region RCW57A which hosts an HII region, a filament, and a bipolar bubble. Polarization measurements of 178 reddened background stars, out of the 919 detected sources in the JHK_s-bands, reveal B-fields that thread perpendicular to the filament long axis. The B-fields exhibit an hour-glass morphology that closely follows the structure of the bipolar bubble. The mean B-field strength, estimated using the Chandrasekhar-Fermi method, is 91 ± 8 μG. B-field pressure dominates over turbulent and thermal pressures. Thermal pressure might act in the same orientation as those of B-fields to accelerate the expansion of those I-fronts. The observed morphological correspondence among the B-fields, filament, and bipolar bubble demonstrate that the B-fields are important to the cloud contraction that formed the filament, gravitational collapse and star formation in it, and in feedback processes. The latter include the formation and evolution of mid-infrared bubbles by means of B-field supported propagation and expansion of I-fronts. These may shed light on preexisting conditions favoring the formation of the massive stellar cluster in RCW57A.

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IN-SYNC VI. Identification and Radial Velocity Extraction for 100+ Double-Lined Spectroscopic Binaries in the APOGEE/IN-SYNC Fields

M.A. Fernandez[1], K.R. Covey[1], N. De Lee[2], S.D. Chojnowski, [3], D. Nidever[4], R. Ballantyne[1], M. Cottaar[5], N. Da Rio[6], J.B. Foster[7], S.R. Majewski[8], M.R. Meyer[9], A.M. Reyna[1], G.W. Roberts[1], J. Skinner[1], K. Stassun[10], J.C. Tan[11], N. Troup[8] and G. Zasowski[12]

[1] Western Washington University, 516 High Street, Bellingham, WA 98225-9164, USA
[2] Northern Kentucky University, Nunn Drive, Highland Heights, KY 41099, USA; Department of Physics & Astronomy, Vanderbilt University, Nashville, TN 37235, USA
[3] Department of Astronomy, New Mexico State University, 1780 E University Avenue, Las Cruces, NM 88003, USA; Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA
[4] National Optical Astronomy Observatory, 950 North Cherry Avenue, Tucson, AZ 85719, USA
[5] Department of Clinical Neurosciences, University of Oxford, Oxford, United Kingdom
[6] Departments of Astronomy and Physics, University of Florida, Gainesville, FL 32611, USA
[7] Yale Center for Astronomy and Astrophysics, Yale University New Haven, CT 06520, USA; Legendary Entertainment Applied Analytics 535 Boylston Street, Suite 401, Boston, MA 02116, USA
[8] Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA
[9] Department of Astronomy, University of Michigan, 1085 S. University, Ann Arbor, MI 48109, USA
[10] Department of Physics & Astronomy, Vanderbilt University, Nashville, TN 37235, USA
[11] Departments of Astronomy and Physics, University of Florida, Gainesville, FL 32611, USA
[12] Department of Physics & Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA

E-mail contact: mfern027 *at* ucr.edu , kevin.covey *at* wwu.edu

We present radial velocity measurements for 70 high confidence, and 34 potential binary systems in fields containing the Perseus Molecular Cloud, Pleiades, NGC 2264, and the Orion A star-forming region. Eighteen of these systems have been previously identified as binaries in the literature. Candidate double-lined spectroscopic binaries (SB2s) are identified by analyzing the cross-correlation functions (CCFs) computed during the reduction of each APOGEE spectrum. We identify sources whose CCFs are well fit as the sum of two Lorentzians as likely binaries, and provide an initial characterization of the system based on the radial velocities indicated by that dual fit. For systems observed over several epochs, we present mass ratios and systemic velocities; for two systems with observations on eight or more epochs, and which meet our criteria for robust orbital coverage, we derive initial orbital parameters. The distribution of mass ratios for multi-epoch sources in our sample peaks at q = 1, but with a significant tail toward lower q values. Tables reporting radial velocities, systemic velocities, and mass ratios are provided online. We discuss future improvements to the radial velocity extraction method we employ, as well as limitations imposed by the number of epochs currently available in the APOGEE database. The Appendix contains brief notes from the literature on each system in the sample, and more extensive notes for select sources of interest.

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Squeezed between shells? On the origin of the Lupus I molecular cloud. - II. APEX CO and GASS HI observations

B. Gaczkowski[1], V. Roccatagliata[2,1], S. Flaischlen[1], D. Kroell[1,3], M.G.H. Krause[5,1,3,4], A. Burkert[1,3], R. Diehl[3,4], K. Fierlinger[1,4], J. Ngoumou[1] and T. Preibisch[1]

[1] Universitaets-Sternwarte München, Ludwig-Maximilians-Universitaet, Scheinerstr. 1, 81679 München, Germany

[2] INAF-Osservatorio Astrofisico di Arcetri, L.go E. Fermi 5, 50125 Firenze, Italy

[3] Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, 85741 Garching, Germany

[4] Excellence Cluster Universe, Boltzmannstrasse 2, 85748 Garching, Germany

[5] School of Mathematics & Physics, Private Bag 37, University of Tasmania, Hobart 7001, Australia

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

Context. The Lupus I cloud is found between the Upper-Scorpius (USco) and the Upper-Centaurus-Lupus (UCL) sub-groups of the Scorpius-Centaurus OB-association, where the expanding USco HI shell appears to interact with a bubble currently driven by the winds of the remaining B-stars of UCL.
Aims. We investigate if the Lupus I molecular could have formed in a colliding flow, and in particular, how the kinematics of the cloud might have been influenced by the larger scale gas dynamics.
Methods. We performed APEX 13CO(2-1) and C18O(2-1) line observations of three distinct parts of Lupus I that provide kinematic information on the cloud at high angular and spectral resolution. We compare those results to the atomic hydrogen data from the GASS HI survey and our dust emission results presented in the previous paper. Based on the velocity information, we present a geometric model for the interaction zone between the USco shell and the UCL wind bubble.
Results. We present evidence that the molecular gas of Lupus I is tightly linked to the atomic material of the USco shell. The CO emission in Lupus I is found mainly at velocities between v(LSR) = 3-6 km/s which is in the same range as the Hi velocities. Thus, the molecular cloud is co-moving with the expanding USco atomic Hi shell. The gas in the cloud shows a complex kinematic structure with several line-of-sight components that overlay each other. The non-thermal velocity dispersion is in the transonic regime in all parts of the cloud and could be injected by external compression. Our observations and the derived geometric model agree with a scenario where Lupus I is located in the interaction zone between the USco shell and the UCL wind bubble.
Conclusions. The kinematics observations are consistent with a scenario where the Lupus I cloud formed via shell instabilities. The particular location of Lupus I between USco and UCL suggests that counter-pressure from the UCL wind bubble and pre-existing density enhancements, perhaps left over from the gas stream that formed the stellar subgroups, may have played a role in its formation.

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Micrometer-Sized Water Ice Particles for Planetary Science Experiments: Influence of Surface Structure on Collisional Properties

S. Gärtner[1], B. Gundlach[2], T. F. Headen[3], J. Ratte[2], J. Oesert[4], S. N. Gorb[4], T. G. A. Youngs[3], D. T. Bowron[3], J. Blum[2] and H. J. Fraser[1]

[1] School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK

[2] Institut für Geophysik und extraterrestrische Physik, TU Braunschweig, Mendelssohnstr. 3, Braunschweig, Germany

[3] ISIS Facility, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK

[4] Zoologisches Institut, Christian-Albrechts-Universität zu Kiel, Am Botanischen Garten 1-9, 24118 Kiel, Germany

E-mail contact: sabrina.gaertner *at* stfc.ac.uk

Models and observations suggest that ice-particle aggregation at and beyond the snowline dominates the earliest stages of planet-formation, which therefore is subject to many laboratory studies. However, the pressure-temperature gradients in proto-planetary disks mean that the ices are constantly processed, undergoing phase changes between different solid phases and the gas phase. Open questions remain as to whether the properties of the icy particles themselves dictate collision outcomes and therefore how effectively collision experiments reproduce conditions in protoplanetary environments. Previous experiments often yielded apparently contradictory results on collision outcomes, only agreeing in a temperature dependence setting in above ≈ 210 K.
By exploiting the unique capabilities of the NIMROD neutron scattering instrument, we characterized the bulk and surface structure of icy particles used in collision experiments, and studied how these structures alter as a function of temperature at a constant pressure of around 30 mbar. Our icy grains, formed under liquid nitrogen, undergo changes in the crystalline ice-phase, sublimation, sintering and surface pre-melting as they are heated from 103 to 247 K. An increase in the thickness of the diffuse surface layer from ≈ 10 to ≈ 30 Å (≈ 2.5 to 12 bilayers) proves increased molecular mobility at temperatures above ≈ 210 K. As none of the other changes tie-in with the temperature trends in collisional outcomes, we conclude that the surface pre-melting phenomenon plays a key role in collision experiments at these temperatures. Consequently, the pressure-temperature environment, may have a larger influence on collision outcomes than previously thought.

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The first frost in the Pipe Nebula

Miwa Goto[1,2], J. D. Bailey[1], Seyit Hocuk[1], Paola Caselli[1], Gisela B. Esplugues[1,3], Stephanie Cazaux[3,4,5] and Marco Spaans[3]

[1] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, 85748, Germany

[2] Universitäts-Sternwarte München, Ludwig-Maximilians-Universität, Scheinerstrasse 1, 81679 München, Germany

[3] Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands

[4] Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands

[5] Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

E-mail contact: mgoto *at* usm.lmu.de

Spectroscopic studies of ices in nearby star-forming regions indicate that ice mantles form on dust grains in two distinct steps, starting with polar ice formation (H_2O rich) and switching to apolar ice (CO rich). We test how well the picture applies to more diffuse and quiescent clouds where the formation of the first layers of ice mantles can be witnessed. Medium-resolution near-infrared spectra are obtained toward background field stars behind the Pipe Nebula. The water ice absorption is positively detected at $3.0\,\mu$m in seven lines of sight out of 21 sources for which observed spectra are successfully reduced. The peak optical depth of the water ice is significantly lower than those in Taurus with the same A_V. The source with the highest water-ice optical depth shows CO ice absorption at $4.7\,\mu$m as well. The fractional abundance of CO ice with respect to water ice is $16^{+7}_{-6}\,\%$, and about half as much as the values typically seen in low-mass star-forming regions. A small fractional abundance of CO ice is consistent with some of the existing simulations. Observations of CO_2 ice in the early diffuse phase of a cloud play a decisive role in understanding the switching mechanism between polar and apolar ice formation.

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Breaking mean-motion resonances during Type I planet migration

T.O. Hands[1,2] and R.D. Alexander[1]

[1] Department of Physics & Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK
[2] Institut für Computergestützte Wissenschaften, Universität Zürich, Winterthurerstrasse 190, Zürich, Switzerland

E-mail contact: tomhands *at* physik.uzh.ch

We present two-dimensional hydrodynamical simulations of pairs of planets migrating simultaneously in the Type I regime in a protoplanetary disc. Convergent migration naturally leads to the trapping of these planets in mean-motion resonances. Once in resonance the planets' eccentricity grows rapidly, and disc-planet torques cause the planets to escape resonance on a time-scale of a few hundred orbits. The effect is more pronounced in highly viscous discs, but operates efficiently even in inviscid discs. We attribute this resonance-breaking to overstable librations driven by moderate eccentricity damping, but find that this mechanism operates differently in hydrodynamic simulations than in previous analytic calculations. Planets escaping resonance in this manner can potentially explain the observed paucity of resonances in Kepler multi-transiting systems, and we suggest that simultaneous disc-driven migration remains the most plausible means of assembling tightly-packed planetary systems.

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How do T Tauri stars accrete?

Lee Hartmann[1] and Jaehan Bae[1,2]

[1] Astronomy Dept., University of Michigan, 1085 S. University Ave., Ann Arbor, MI 48109, USA
[2] Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, USA

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

We conjecture that observed protoplanetary disc accretion rates may be explained with low viscosities which could be the result of hydrodynamic turbulence. We show that viscosities parameterized in the usual way with $\alpha \gtrsim 10^{-4}$, comparable to values suggested for hydrodynamic turbulence, can explain the observed accretion rates and lifetimes with plausible inner disc surface densities. Our models are also in better agreement with surface density estimates of the minimum mass solar nebula than models with rapid transport for a given mass accretion rate, such as recent models of accretion driven by magnetic winds. The required surface densities are a natural result of the protostellar infall phase, as long as non-gravitational transport is limited. We argue that, in addition to possible non-ideal magnetic transport due to disc winds possibly modified by the Hall effect, the effects of low-viscosity hydrodynamic accretion deserve more consideration.

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Harvesting the decay energy of ^{26}Al to drive lightning discharge in protoplanetary discs

Anders Johansen[1] and Satoshi Okuzumi[2]

[1] Lund Observatory, Department of Astronomy and Theoretical Physics, Lund University, Sweden
[2] Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Japan

E-mail contact: anders *at* astro.lu.se

Chondrules in primitive meteorites likely formed by recrystallisation of dust aggregates that were flash-heated to nearly complete melting. Chondrules may represent the building blocks of rocky planetesimals and protoplanets in the inner regions of protoplanetary discs, but the source of ubiquitous thermal processing of their dust aggregate precursors remains elusive. Here we demonstrate that escape of positrons released in the decay of the short-lived radionuclide ^{26}Al leads to a large-scale charging of dense pebble structures, resulting in neutralisation by lightning discharge and flash-heating of dust and pebbles. This charging mechanism is similar to a nuclear battery where a radioactive source charges a capacitor. We show that the nuclear battery effect operates in circumplanetesimal pebble discs. The extremely high pebble densities in such discs are consistent with conditions during chondrule heating

inferred from the high abundance of sodium within chondrules. The sedimented mid-plane layer of the protoplanetary disc may also be prone to charging by the emission of positrons, if the mass density of small dust there is at least an order of magnitude above the gas density. Our results imply that the decay energy of ^{26}Al can be harvested to drive intense lightning activity in protoplanetary discs. The total energy stored in positron emission is comparable to the energy needed to melt all solids in the protoplanetary disc. The efficiency of transferring the positron energy to the electric field nevertheless depends on the relatively unknown distribution and scale-dependence of pebble density gradients in circumplanetesimal pebble discs and in the protoplanetary disc mid-plane layer.

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The Green Bank Ammonia Survey: Observations of Hierarchical Dense Gas Structures in Cepheus-L1251

Jared Keown[1], James Di Francesco[1,2], Helen Kirk[2], Rachel K. Friesen[3], Jaime E. Pineda[4], Erik Rosolowsky[5], Adam Ginsburg[6], Stella S. R. Offner[7], Paola Caselli[4], Felipe Alves[4], Ana Chacon-Tanarro[4], Anna Punanova[4], Elena Redaelli[4], Young Min Seo[8], Christopher D. Matzner[9], Michael Chun-Yuan Chen[1], Alyssa A. Goodman[10], How-Huan Chen[10], Yancy Shirley[11], Ayushi Singh[9], Hector G. Arce[12], Peter Martin[13] and Philip C. Myers[10]

[1] Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 5C2, Canada
[2] NRC Herzberg Astronomy and Astrophysics, 5071 West Saanich Road, Victoria, BC, V9E 2E7, Canada
[3] Dunlap Institute for Astronomy and Astrophysics, University of Toronto, 50 St. George St., Toronto, ON, M5S 3H4, Canada
[4] Max-Planck-Institut fur extraterrestrische Physik, Giessenbachstrasse 1, D-85748, Garching, Germany
[5] Department of Physics, University of Alberta, Edmonton, AB, Canada
[6] National Radio Astronomy Observatory, Socorro, NM 87801, USA
[7] Department of Astronomy, The University of Texas, Austin, TX 78712, USA
[8] Jet Propulsion Laboratory, NASA, 4800 Oak Grove Dr, Pasadena, CA 91109, USA
[9] Department of Astronomy & Astrophysics, University of Toronto, 50 St. George Street, Toronto, Ontario, Canada M5S 3H4
[10] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA
[11] Steward Observatory, 933 North Cherry Avenue, Tucson, AZ 85721, USA
[12] Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520-8101, USA
[13] Canadian Institute for Theoretical Astrophysics, University of Toronto, 60 St. George St., Toronto, Ontario, Canada, M5S 3H8

E-mail contact: jkeown *at* uvic.ca

We use Green Bank Ammonia Survey observations of NH_3 (1,1) and (2,2) emission with 32" FWHM resolution from a ~ 10 pc^2 portion of the Cepheus-L1251 molecular cloud to identify hierarchical dense gas structures. Our dendrogram analysis of the NH_3 data results in 22 top-level structures, which reside within 13 lower-level, parent structures. The structures are compact (0.01 pc $< R_{eff} <$ 0.1 pc) and are spatially correlated with the highest H_2 column density portions of the cloud. We also compare the ammonia data to a catalog of dense cores identified by higher-resolution (18.2" FWHM) *Herschel Space Observatory* observations of dust continuum emission from Cepheus-L1251. Maps of kinetic gas temperature, velocity dispersion, and NH_3 column density, derived from detailed modeling of the NH_3 data, are used to investigate the stability and chemistry of the ammonia-identified and *Herschel*-identified structures. We show that the dust and dense gas in the structures have similar temperatures, with median T_{dust} and T_K measurements of 11.7 ± 1.1 K and 10.3 ± 2.0 K, respectively. Based on a virial analysis, we find that the ammonia-identified structures are gravitationally dominated, yet may be in or near a state of virial equilibrium. Meanwhile, the majority of the *Herschel*-identified dense cores appear to be not bound by their own gravity and instead confined by external pressure. CCS $(2_0 - 1_0)$ and HC_5N $(9-8)$ emission from the region reveal broader line widths and centroid velocity offsets when compared to the NH_3 (1,1) emission in some cases, likely due to these carbon-based molecules tracing the turbulent outer layers of the dense cores.

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The FluxCompensator: Making Radiative Transfer Models of hydrodynamical Simulations Directly Comparable to Real Observations

Christine M. Koepferl[1] and Thomas P. Robitaille[2]

[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany
[2] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; Freelance Consultant, Headingley Enterprise and Arts Centre, Bennett Road Headingley, Leeds LS6 3HN

E-mail contact: koepferl *at* usm.lmu.de

When modeling astronomical objects throughout the universe, it is important to correctly treat the limitations of the data, for instance finite resolution and sensitivity. In order to simulate these effects, and to make radiative transfer models directly comparable to real observations, we have developed an open-source Python package called the FluxCompensator that enables the post-processing of the output of 3-d Monte-Carlo radiative transfer codes, such as HYPERION. With the FluxCompensator, realistic synthetic observations can be generated by modelling the effects of convolution with arbitrary point-spread functions (PSFs), transmission curves, finite pixel resolution, noise and reddening. Pipelines can be applied to compute synthetic observations that simulate observatories, such as the Spitzer Space Telescope or the Herschel Space Observatory. Additionally, this tool can read in existing observations (e.g. FITS format) and use the same settings for the synthetic observations. In this paper, we describe the package as well as present examples of such synthetic observations.

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Insights from Synthetic Star-forming Regions: I. Reliable Mock Observations from SPH Simulations

Christine M. Koepferl[1], Thomas P. Robitaille[2], James E. Dale[3] and Francesco Biscani[4]

[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; University of St Andrews, North Haugh, St Andrews, UK; University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany
[2] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; Freelance Consultant, Headingley Enterprise and Arts Centre, Bennett Road Headingley, Leeds LS6 3HN
[3] University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany
[4] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg

E-mail contact: koepferl *at* usm.lmu.de

Through synthetic observations of a hydrodynamical simulation of an evolving star-forming region, we assess how the choice of observational techniques affects the measurements of properties which trace star formation. Testing and calibrating observational measurements requires synthetic observations which are as realistic as possible. In this part of the paper series (Paper I), we explore different techniques for how to map the distributions of densities and temperatures from the particle-based simulations onto a Voronoi mesh suitable for radiative transfer and consequently explore their accuracy. We further test different ways to set up the radiative transfer in order to produce realistic synthetic observations. We give a detailed description of all methods and ultimately recommend techniques. We have found that the flux around 20 microns is strongly overestimated when blindly coupling the dust radiative transfer temperature with the hydrodynamical gas temperature. We find that when instead assuming a constant background dust temperature in addition to the radiative transfer heating, the recovered flux is consistent with actual observations. We present around 5800 realistic synthetic observations for Spitzer and Herschel bands, at different evolutionary time-steps, distances and orientations. In the upcoming papers of this series (Paper II, Paper III and Paper IV), we will test and calibrate measurements of the star-formation rate (SFR), gas mass and the star-formation efficiency (SFE) using our realistic synthetic observations.

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Insights from Synthetic Star-forming Regions: II. Verifying Dust Surface Density, Dust Temperature & Gas Mass Measurements with Modified Blackbody Fitting

Christine M. Koepferl[1], Thomas P. Robitaille[2] and James E. Dale[3]

[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; University of St Andrews, North Haugh, St Andrews, UK; University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany
[2] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; Freelance Consultant, Headingley Enterprise and Arts Centre, Bennett Road Headingley, Leeds LS6 3HN
[3] University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany

E-mail contact: koepferl *at* usm.lmu.de

We use a large data-set of realistic synthetic observations (Paper I) to assess how observational techniques affect the measurement of physical properties of star-forming regions. In this paper (PaperII), we explore the reliability of the measured total gas mass, dust surface density and dust temperature maps derived from modified blackbody fitting of synthetic Herschel observations. We found from our pixel-by-pixel analysis of the measured dust surface density and dust temperature a worrisome error spread especially close to star-formation sites and low-density regions, where for those "contaminated" pixels the surface densities can be under/overestimated by up to three orders of magnitude. In light of this, we recommend to treat the pixel-based results from this technique with caution in regions with active star formation. In regions of high background typical in the inner Galactic plane, we are not able to recover reliable surface density maps of individual synthetic regions, since low-mass regions are lost in the FIR background. When measuring the total gas mass of regions in moderate background, we find that modified blackbody fitting works well (absolute error:+910kpc distance (errors increase with distance). Commonly, the initial images are convolved to the largest common beam-size, which smears contaminated pixels over large areas. The resulting information loss makes this commonly-used technique less verifiable as now chi^2-values cannot be used as a quality indicator of a fitted pixel. Our control measurements of the total gas mass (without the step of convolution to the largest common beam size) produce similar results (absolute error:+20%;-7%) while having much lower median errors especially for the high-mass stellar feedback phase. In upcoming papers (Paper III & IV) we test the reliability of measured star-formation rate with direct and indirect techniques.

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Insights from Synthetic Star-forming Regions: III. Calibration of Measurement Techniques of Star-formation Rates

Christine M. Koepferl[1], Thomas P. Robitaille[2] and James E. Dale[3]

[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; University of St Andrews, North Haugh, St Andrews, UK; University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany
[2] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; Freelance Consultant, Headingley Enterprise and Arts Centre, Bennett Road Headingley, Leeds LS6 3HN
[3] University Observatory Munich, Scheinerstr. 1, D-81679 Munich, Germany

E-mail contact: koepferl *at* usm.lmu.de

Through an extensive set of realistic synthetic observations (produced in Paper I), we assess in this part of the paper series (Paper III) how the choice of observational techniques affects the measurement of star-formation rates (SFRs) in star-forming regions. We test the accuracy of commonly used techniques and construct new methods to extract the SFR, so that these findings can be applied to measure the SFR in real regions throughout the Milky Way. We investigate diffuse infrared SFR tracers such as those using 24 microns, 70 microns and total infrared emission, which have been previously calibrated for global galaxy scales. We set up a toy model of a galaxy and show that the infrared emission is consistent with the intrinsic SFR using extra-galactic calibrated laws (although the consistency does not prove their reliability). For local scales, we show that these techniques produce completely unreliable results for single star-forming regions, which are governed by different characteristic timescales. We show how calibration of these techniques can be improved for single star-forming regions by adjusting the characteristic timescale and the scaling factor and give suggestions of new calibrations of the diffuse star-formation tracers. We show that star-forming regions that are dominated by high-mass stellar feedback experience a rapid drop in infrared emission once high-mass stellar feedback is turned on, which implies different characteristic timescales. Moreover, we explore the measured SFRs calculated directly from the observed young stellar population. We find that the measured point sources follow the evolutionary pace of star formation more directly than diffuse star-formation tracers.

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FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45-m telescope (FUGIN): Molecular clouds toward W33; possible evidence for a cloud-cloud collision triggering O star formation

Mikito Kohno[1], Kazufumi Torii[2], Kengo Tachihara[1], Tomofumi Umemoto[2,3], Tetsuhiro Minamidani[2,3], Atsushi Nishimura[1], Shinji Fujita[1], Mitsuhiro Matsuo[2], Mitsuyoshi Yamagishi[4], Yuya Tsuda[5], Mika Kuriki[6], Nario Kuno[6], Akio Ohama[1], Yusuke Hattori[1], Hidetoshi Sano[1,7], Hiroaki Yamamoto[1] and Yasuo Fukui[1,7]

[1] Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8601, Japan

[2] Nobeyama Radio Observatory, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences (NINS), 462-2, Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan

[3] Department of Astronomical Science, School of Physical Science, SOKENDAI (The Graduate University for Advanced Studies), 2-21-1, Osawa, Mitaka, Tokyo 181-8588, Japan

[4] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Chuo-ku, Sagamihara, Japan

[5] Graduate School of Science and Engineering, Meisei University, 2-1-1 Hodokubo, Hino, Tokyo 191-0042, Japan

[6] Department of Physics, Graduate School of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Ten-nodai, tsukuba, Ibaraki 305-8577, Japan

[7] Institute for Advanced Research, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

E-mail contact: mikito *at* a.phys.nagoya-u.ac.jp

We observed molecular clouds in the W33 high-mass star-forming region associated with compact and extended HII regions using the NANTEN2 telescope as well as the Nobeyama 45-m telescope in the J =1–0 transitions of ^{12}CO, ^{13}CO, and C^{18}O as a part of the FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45-m telescope (FUGIN) legacy survey. We detected three velocity components at 35 km s^{-1}, 45 km s^{-1}, and 58 km s^{-1}. The 35 km s^{-1} and 58 km s^{-1} clouds are likely to be physically associated with W33 because of the enhanced ^{12}CO J = 3–2 to J =1–0 intensity ratio as $R_{3-2/1-0} > 1.0$ due to the ultraviolet irradiation by OB stars, and morphological correspondence between the distributions of molecular gas and the infrared and radio continuum emissions excited by high-mass stars. The two clouds show complementary distributions around W33. The velocity separation is too large to be gravitationally bound, and yet not explained by expanding motion by stellar feedback. Therefore, we discuss that a cloud-cloud collision scenario likely explains the high-mass star formation in W33.

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Dust-trapping vortices and a potentially planet-triggered spiral wake in the pre-transitional disk of V1247 Orionis

Stefan Kraus[1], Alexander Kreplin[1], Misato Fukugawa[2], Takayuki Muto[3], Michael L. Sitko[4], Alison K. Young[1], Matthew R. Bate[1], Carol Grady[5], Tim T. Harries[1], John D. Monnier[6], Matthew Willson[1], John Wisniewski[7]

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

[2] Division of Particle and Astrophysical Science, Graduate School of Science, Nagoya University, Nagoya, Japan

[3] Division of Liberal Arts, Kogakuin University, 1-24-2 Nishi-Shinjuku, Shinjuku-ku, Tokyo, 163-8677, Japan

[4] Department of Physics, University of Cincinnati, Cincinnati, OH 45221, USA; Center for Extrasolar Planetary Systems, Space Science Institute, 4750 Walnut Street, Suite 205, Boulder, CO 80301, USA

[5] Eureka Scientific, 2452 Delmer Street, Suite 100, Oakland CA 96402, USA

[6] Dept. of Astronomy, University of Michigan, 311 West Hall, 1085 South University Ave, Ann Arbor, MI 48109, USA

[7] Homer L. Dodge Department of Physics, University of Oklahoma, Norman, OK 73071, USA

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

The radial drift problem constitutes one of the most fundamental problems in planet formation theory, as it predicts particles to drift into the star before they are able to grow to planetesimal size. Dust-trapping vortices have been proposed as a possible solution to this problem, as they might be able to trap particles over millions of years, allowing them to grow beyond the radial drift barrier. Here, we present ALMA 0.″04-resolution imaging of the pre-transitional disk of V1247 Orionis that reveals an asymmetric ring as well as a sharply-confined crescent structure, resembling morphologies seen in theoretical models of vortex formation. The asymmetric ring (at 0.″17=54 au separation from the star) and the crescent (at 0.″38=120 au) seem smoothly connected through a one-armed spiral arm structure that has been found previously in scattered light. We propose a physical scenario with a planet orbiting at $\sim$0.″3≈100 au, where the one-armed spiral arm detected in polarised light traces the accretion stream feeding the protoplanet. The dynamical influence of the planet clears the gap between the ring and the crescent and triggers two vortices that trap mm-sized particles, namely the crescent and the bright asymmetry seen in the ring. We conducted dedicated hydrodynamics simulations of a disk with an embedded planet, which results in similar spiral-arm morphologies as seen in our scattered light images. At the position of the spiral wake and the crescent we also observe ^{12}CO (3–2) and $H^{12}CO^+$ (4–3) excess line emission, likely tracing the increased scale-height in these disk regions.

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The Structure of the Young Star Cluster NGC 6231. II. Structure, Formation, and Fate

Michael A. Kuhn[1,2], Konstantin V. Getman[3], Eric D. Feigelson[3,1], Alison Sills[4], Mariusz Gromadzki[5,1,2], Nicolás Medina[1,2], Jordanka Borissova[1,2] and Radostin Kurtev[1,2]

[1] Millennium Institute of Astrophysics, Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile
[2] Instituto de Fisica y Astronomía, Universidad de Valparaíso, Gran Bretaña 1111, Playa Ancha, Valparaíso, Chile
[3] Department of Astronomy & Astrophysics, 525 Davey Laboratory, Pennsylvania State University, University Park, PA 16802, USA
[4] Department of Physics & Astronomy, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4M1, Canada
[5] Warsaw University Astronomical Observatory, Al. Ujazdowskie 4, 00-478 Warszawa, Poland

E-mail contact: mkuhn1 *at* gmail.com

The young cluster NGC 6231 (stellar ages $\sim$2–7 Myr) is observed shortly after star-formation activity has ceased. Using the catalog of 2148 probable cluster members obtained from *Chandra*, VVV, and optical surveys (Paper I), we examine the cluster's spatial structure and dynamical state. The spatial distribution of stars is remarkably well fit by an isothermal sphere with moderate elongation, while other commonly used models like Plummer spheres, multivariate normal distributions, or power-law models are poor fits. The cluster has a core radius of 1.2 ± 0.1 pc and a central density of $\sim$200 stars pc^{-3}. The distribution of stars is mildly mass segregated. However, there is no radial stratification of the stars by age. Although most of the stars belong to a single cluster, a small subcluster of stars is found superimposed on the main cluster, and there are clumpy non-isotropic distributions of stars outside $\sim$4 core radii. When the size, mass, and age of NGC 6231 are compared to other young star clusters and subclusters in nearby active star-forming regions, it lies at the high-mass end of the distribution but along the same trend line. This could result from similar formation processes, possibly hierarchical cluster assembly. We argue that NGC 6231 has expanded from its initial size but that it remains gravitationally bound.

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The Parsec-Scale Relationship Between $I_{\rm CO}$ and $A_{\rm V}$ in Local Molecular Clouds

Cheoljong Lee[1], Adam K. Leroy[2], Alberto D. Bolatto[3], Simon C.O. Glover[4], Remy Indebetouw[1,5], Karin Sandstrom[6], and Andreas Schruba[7]

[1] Department of Astronomy, University of Virginia, Charlottesville, VA 22904, USA
[2] Department of Astronomy, The Ohio State University, 140 West 18th Avenue, Columbus, OH, 43210, USA

[3] Department of Astronomy, Laboratory for Millimeter-wave Astronomy, and Joint Space Institute, University of Maryland, College Park, Maryland 20742, USA
[4] Institute für theoretische Astrophysik, Zentrum für Astronomie der Universität Heidelberg, Albert-Ueberle Str. 2, 69120 Heidelberg, Germany
[5] National Radio Astronomy Observatory, 520 Edgemont Rd, Charlottesville, VA 22903, USA
[6] Center for Astrophysics and Space Sciences, Department of Physics, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA
[7] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstraße 1, 85748 Garching, Germany

E-mail contact: leroy.42 *at* osu.edu

We measure the parsec-scale relationship between integrated CO intensity ($I_{\rm CO}$) and visual extinction ($A_{\rm V}$) in 24 local molecular clouds using maps of CO emission and dust optical depth from Planck. This relationship informs our understanding of CO emission across environments, but clean Milky Way measurements remain scarce. We find uniform $I_{\rm CO}$ for a given $A_{\rm V}$, with the results bracketed by previous studies of the Pipe and Perseus clouds. Our measured $I_{\rm CO}$–$A_{\rm V}$ relation broadly agrees with the standard Galactic CO-to-H_2 conversion factor, the relation found for the Magellanic clouds at coarser resolution, and numerical simulations by Glover & Clark (2016). This supports the idea that CO emission primarily depends on shielding, which protects molecules from dissociating radiation. Evidence for CO saturation at high $A_{\rm V}$ and a threshold for CO emission at low $A_{\rm V}$varies remains uncertain due to insufficient resolution and ambiguities in background subtraction. Resolution of order 0.1 pc may be required to measure these features. We use this $I_{\rm CO}$–$A_{\rm V}$ relation to predict how the CO-to-H_2 conversion factor ($X_{\rm CO}$) would change if the Solar Neighborhood clouds had different dust-to-gas ratio (metallicity). The calculations highlight the need for improved observations of the CO emission threshold and HI shielding layer depth. They are also sensitive to the shape of the column density distribution. Because local clouds collectively show a self-similar distribution, we predict a shallow metallicity dependence for $X_{\rm CO}$ down to a few tenths of solar metallicity. However, our calculations also imply dramatic variations in cloud-to-cloud $X_{\rm CO}$ at subsolar metallicity.

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The Formation of Stellar Clusters in Magnetized, Filamentary Infrared Dark Clouds

Pak Shing Li[1], Richard I. Klein[1,2] and Christopher F. McKee[1,3]

[1] Astronomy Department, University of California, Berkeley, CA 94720, USA
[2] Lawrence Livermore National Laboratory,P.O.Box 808, L-23, Livermore, CA 94550, USA
[3] Physics Department, University of California, Berkeley, CA 94720, USA

E-mail contact: psli *at* berkeley.edu

Star formation in a filamentary infrared dark cloud (IRDC) is simulated over a dynamic range of 4.2 pc to 28 au for a period of 3.5×10^5 yr, including magnetic fields and both radiative and outflow feedback from the protostars. At the end of the simulation, the star formation efficiency is 4.3 per cent and the star formation rate per free fall time is eff$\simeq 0.04$, within the range of observed values (Krumholz et al. 2012a). The total stellar mass increases as $\sim t^2$, whereas the number of protostars increases as $\sim t^{1.5}$. We find that the density profile around most of the simulated protostars is $\sim \rho \propto r^{-1.5}$, as predicted by Murray & Chang (2015). At the end of the simulation, the protostellar mass function approaches the Chabrier (2005) stellar initial mass function. We infer that the time to form a star of median mass $0.2\,M_\odot$ is about 1.4×10^5 yr from the median mass accretion rate. We find good agreement among the protostellar luminosities observed in the large sample of Dunham et al. (2013), our simulation, and a theoretical estimate, and conclude that the classical protostellar luminosity problem (Kenyon et al. 1990) is resolved. The multiplicity of the stellar systems in the simulation agrees to within a factor 2 of observations of Class I young stellar objects; most of the simulated multiple systems are unbound. Bipolar protostellar outflows are launched using a sub-grid model, and extend up to 1 pc from their host star. The mass-velocity relation of the simulated outflows is consistent with both observation and theory.

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A 1.3 mm SMA Survey of 29 Variable Young Stellar Objects

Hauyu Baobab Liu[1], Michael M. Dunham[2,3], Ilaria Pascucci[4], Tyler L. Bourke[5], Naomi Hirano[6], Steven Longmore[7], Sean Andrews[3], Carlos Carrasco-González[8], Jan Forbrich[9], Roberto Galván-Madrid[8], Josep M. Girart[10], Joel D. Green[11], Carmen Juárez[10], Ágnes Kóspal[12,13], Carlo F. Manara[1], Aina Palau[8], Michihiro Takami[6], Leonardo Testi[1] and Eduard I. Vorobyov[14,15,16]

[1] European Southern Observatory (ESO), Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany
[2] Department of Physics, State University of New York at Fredonia, 280 Central Ave, Fredonia, NY 14063
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[4] Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA
[5] SKA Organisation, Jodrell Bank Observatory, Lower Withington, Macclesfield SK11 9DL, UK
[6] Institute of Astronomy and Astrophysics, Academia Sinica, 11F of Astronomy-Mathematics Building, National Taiwan University, No 1, Sec., Roosevelt Road, Taipei, 10617 Taiwan
[7] Astrophysics Research Institute, Liverpool John Moores University, IC2, Liverpool Science Park, 146 Brownlow Hill, Liverpool L3 5RF, UK
[8] Instituto de Radioastronomía y Astrofísica, UNAM, A.P. 3-72, Xangari, Morelia, 58089, Mexico
[9] Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, University of Hertfordshire, College Lane, Hatfield AL10 9AB, UK
[10] Institut de Ciències de l'Espai (IEEC-CSIC), Can Magrans, S/N, E-08193 Cerdanyola del Vallés, Catalonia, Spain
[11] Space Telescope Science Institute, Baltimore, MD 21218, USA
[12] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Hungarian Academy of Science, Konkoly-Thege Miklósút 15-17, 1121 Budapest, Hungary
[13] Max-Planck-Institut för Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[14] Institute of Fluid Mechanics and Heat Transfer, TU Wien, 1060 Vienna, Austria
[15] Department of Astrophysics, University of Vienna, Vienna 1180, Austria
[16] Research Institute of Physics, Southern Federal University, Rostov-on-Don 344090, Russia

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

Young stellar objects (YSOs) may undergo periods of active accretion (outbursts), during which the protostellar accretion rate is temporarily enhanced by a few orders of magnitude. Whether or not these accretion outburst YSOs possess similar dust/gas reservoirs to each other, and whether or not their dust/gas reservoirs are similar as quiescent YSOs, are issues not yet clarified. The aim of this work is to characterize the millimeter thermal dust emission properties of a statistically significant sample of long and short duration accretion outburst YSOs (i.e., FUors and EXors) and the spectroscopically identified candidates of accretion outbursting YSOs (i.e., FUor-like objects). We have carried out extensive Submillimeter Array (SMA) observations mostly at ∼225 GHz (1.33 mm) and ∼272 GHz (1.10 mm), from 2008 to 2017. We covered accretion outburst YSOs located at <1 kpc distances from the solar system. We analyze all the existing SMA data of such objects, both published and unpublished, in a coherent way to present a millimeter interferometric database of 29 objects. We obtained 21 detections at >3-σ significance. Detected sources except for the two cases of V883 Ori and NGC 2071 MM3 were observed with ∼1″ angular resolution. Overall our observed targets show a systematically higher millimeter luminosity distribution than those of the $M_* > 0.3\ M_\odot$ Class II YSOs in the nearby ($\lesssim$400 pc) low-mass star-forming molecular clouds (e.g., Taurus, Lupus, Upp Scorpio, and Chameleon I). In addition, at 1 mm our observed confirmed binaries or triple-system sources are systematically fainter than the rest of the sources even though their 1 mm fluxes are broadly distributed. We may have detected ∼30-60% millimeter flux variability from V2494 Cyg and V2495 Cyg, from the observations separated by ∼1 year.

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ALMA Reveals Sequential High-mass Star Formation in the G9.62+0.19 Complex

Tie Liu[1], John Lacy[2], Pak Shing Li[3], Ke Wang[4], Sheng-Li Qin[5], Qizhou Zhang[6], Kee-Tae Kim[1], Guido Garay[7], Yuefang Wu[8], Diego Mardones[7], Qingfeng Zhu[9], Ken'ichi Tatematsu[10], Tomoya Hirota[10], Zhiyuan Ren[11], Sheng-Yuan Liu[12], Huei-Ru Chen[12], Yu-Nung Su[12] and Di Li[11]

[1] Korea Astronomy and Space Science Institute 776, Daedeokdae-ro, Yuseong-gu, Daejeon, Korea
[2] Department of Astronomy, University of Texas at Austin, Austin, TX 78712, USA

[3] Astronomy Department, University of California, Berkeley, CA 94720, USA
[4] European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching bei Mnchen, Germany
[5] Department of Astronomy, Yunnan University, and Key Laboratory of Astroparticle Physics of Yunnan Province, Kunming, 650091, China
[6] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[7] Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago, Chile
[8] Department of Astronomy, Peking University, Beijing 100871, China
[9] Astronomy Department, University of Science and Technology, Chinese Academy of Sciences, Hefei 210008, China
[10] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo
[11] National Astronomical Observatories, Chinese Academy of Science, A20 Datun Road, Chaoyang District, Beijing 100012, China
[12] Academia Sinica, Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 106, Taiwan

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

Stellar feedback from high-mass stars (e.g., HII regions) can strongly influence the surrounding interstellar medium and regulate star formation. Our new ALMA observations reveal sequential high-mass star formation taking place within one subvirial filamentary clump (the G9.62 clump) in the G9.62+0.19 complex. The 12 dense cores (MM1-MM12) detected by ALMA are at very different evolutionary stages, from the starless core phase to the UC HII region phase. Three dense cores (MM6, MM7/G, MM8/F) are associated with outflows. The mass-velocity diagrams of the outflows associated with MM7/G and MM8/F can be well-fit by broken power laws. The mass-velocity diagram of the SiO outflow associated with MM8/F breaks much earlier than other outflow tracers (e.g., CO, SO, CS, HCN), suggesting that SiO traces newly shocked gas, while the other molecular lines (e.g., CO, SO, CS, HCN) mainly trace the ambient gas continuously entrained by outflow jets. Five cores (MM1, MM3, MM5, MM9, MM10) are massive starless core candidates whose masses are estimated to be larger than 25 $M_\odot$, assuming a dust temperature of $\lesssim$20 K. The shocks from the expanding HII regions ("B" and "C") to the west may have a great impact on the G9.62 clump by compressing it into a filament and inducing core collapse successively, leading to sequential star formation. Our findings suggest that stellar feedback from H ii regions may enhance the star formation efficiency and suppress low-mass star formation in adjacent pre-existing massive clumps.

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The JCMT Transient Survey: Identifying Submillimetre Continuum Variability over Several Year Timescales Using Archival JCMT Gould Belt Survey Observations

Steve Mairs[1,2], Doug Johnstone[1,2], Helen Kirk[2], James Lane[1], Graham S. Bell[3], Sarah Graves[3], Gregory J. Herczeg[4], Peter Scicluna[5], Geoffrey C. Bower[6], Huei-Ru Vivien Chen[7], Jennifer Hatchell[8], Yuri Aikawa[9], Wen-Ping Chen[10], Miju Kang[11], Sung-Ju Kang[11], Jeong-Eun Lee[12], Oscar Morata[13], Andy Pon[14], Aleks Scholz[15], Satoko Takahashi[16,17] and Hyunju Yoo[12,18]

[1] Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada
[2] NRC Herzberg Astronomy and Astrophysics, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada
[3] East Asian Observatory, 660 North Aohoku Place, University Park, Hilo, Hawaii 96720, USA
[4] Kavli Institute for Astronomy and Astrophysics, Peking University, Yiheyuan 5, Haidian Qu, 100871 Beijing, Peoples Republic of China
[5] Academia Sinica Institute of Astronomy and Astrophysics, P. O. Box 23-141, Taipei 10617, Taiwan
[6] Academia Sinica Institute of Astronomy and Astrophysics, 645 N. Aohoku Place, Hilo, HI 96720, USA
[7] Department of Physics and Institute of Astronomy, National Tsing Hua University, Taiwan
[8] Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK
[9] Department of Astronomy, University of Tokyo, Tokyo, Japan
[10] Graduate Institute of Astronomy, National Central University, 300 Jhongda Road, Zhongli, Taoyuan, Taiwan
[11] Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Republic of Korea
[12] School of Space Research, Kyung Hee University, 1732, Deogyeong-Daero, Giheung-gu Yongin-shi, Gyunggi-do 17104, Korea

[13] Academia Sinica Institute of Astronomy and Astrophysics, 11F of AS/NTU Astronomy-Mathematics Building, No.1, Sec. 4, Roosevelt Rd, Taipei 10617, Taiwan
[14] Department of Physics and Astronomy, The University of Western Ontario, 1151 Richmond Street, London, ON, N6A 3K7, Canada
[15] SUPA, School of Physics & Astronomy, North Haugh, St Andrews, KY16 9SS, United Kingdom
[16] Joint ALMA Observatory, Alonso de Cordova 3107, Vitacura, Santiago, Chile
[17] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[18] Department of Astronomy and Space Science, Chungnam National University, 99 Daehak-ro, Yuseong-gu, Daejeon 34134, Republic of Korea

E-mail contact: s.mairs *at* eaobservatory.org

Investigating variability at the earliest stages of low-mass star formation is fundamental in understanding how a protostar assembles mass. While many simulations of protostellar disks predict non-steady accretion onto protostars, deeper investigation requires robust observational constraints on the frequency and amplitude of variability events characterised across the observable SED. In this study, we develop methods to robustly analyse repeated observations of an area of the sky for submillimetre variability in order to determine constraints on the magnitude and frequency of deeply embedded protostars. We compare 850 μm JCMT Transient Survey data with archival JCMT Gould Belt Survey data to investigate variability over 2-4 year timescales. Out of 175 bright, independent emission sources identified in the overlapping fields, we find 7 variable candidates, 5 of which we classify as *Strong* and the remaining 2 as *Extended* to indicate the latter are associated with larger-scale structure. For the *Strong* variable candidates, we find an average fractional peak brightness change per year of $|4.0|\%\,\mathrm{yr}^{-1}$ with a standard deviation of $2.7\%\,\mathrm{yr}^{-1}$. In total, 7% of the protostars associated with 850 μm emission in our sample show signs of variability. Four of the five *Strong* sources are associated with a known protostar. The remaining source is a good follow-up target for an object that is anticipated to contain an enshrouded, deeply embedded protostar. In addition, we estimate the 850 μm periodicity of the submillimetre variable source, EC 53, to be 567 ± 32 days based on the archival Gould Belt Survey data.

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A turbulent origin for the complex envelope kinematics in the young low-mass core Per-Bolo 58

Maria Jose Maureira[1], Hector G. Arce[1], Stella S. R. Offner[2], Michael M. Dunham[3], Jaime E. Pineda[4], Manuel Fernandez-Lopez[5], Xuepeng Chen[6] and Diego Mardones[7]

[1] Astronomy Department, Yale University, New Haven, CT 06511, USA
[2] Department of Astronomy, The University of Texas at Austin, Austin, TX, 78712
[3] Department of Physics, State University of New York at Fredonia, Fredonia, NY 14063, USA
[4] Max-Planck Institute for Extraterrestrial Physics, Giessenbachstrasse 1, 85748 Garching, Germany
[5] Instituto Argentino de Radioastronoma (CCT-La Plata, CONICET; CICPBA), C.C. No. 5, 1894,Villa Elisa, Argentina
[6] Purple Mountain Observatory, Chinese Academy of Sciences, 2 West Beijing Road, Nanjing 210008, China
[7] Departamento de Astronoma, Universidad de Chile, Casilla 36-D, Santiago, Chile

E-mail contact: mariajose.maureira *at* yale.edu

We use CARMA 3mm continuum and molecular lines (NH_2D, N_2H^+, HCO^+, HCN and CS) at $\sim$1000 au resolution to characterize the structure and kinematics of the envelope surrounding the deeply embedded first core candidate Per-Bolo 58. The line profile of the observed species shows two distinct peaks separated by 0.4-0.6 $\mathrm{km\,s^{-1}}$, most likely arising from two different optically thin velocity components rather than the product of self-absorption in an optically thick line. The two velocity components, each with a mass of $\sim$0.5-0.6 $M_\odot$, overlap spatially at the position of the continuum emission, and produce a general gradient along the outflow direction. We investigate whether these observations are consistent with infall in a turbulent and magnetized envelope. We compare the morphology and spectra of the N_2H^+(1-0) with synthetic observations of an MHD simulation that considers the collapse of an isolated core that is initially perturbed with a turbulent field. The proposed model matches the data in the production of two velocity components, traced by the isolated hyperfine line of the N_2H^+(1-0) spectra and shows a general agreement

in morphology and velocity field. We also use large maps of the region to compare the kinematics of the core with that of the surrounding large-scale filamentary structure and find that accretion from the large-scale filament could also explain the complex kinematics exhibited by this young dense core.

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Forming spectroscopic massive proto-binaries by disk fragmentation

D.M.-A. Meyer[1], R. Kuiper[1], W. Kley[1], K.G. Johnston[2] and E. Vorobyov[3,4,5]

[1] Institut für Astronomie und Astrophysik, Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen, Germany
[2] School of Physics and Astronomy, E.C. Stoner Building, The University of Leeds, Leeds LS2 9JT, UK
[3] Institute of Fluid Mechanics and Heat Transfer, TU Wien, Vienna, 1060, Austria
[4] Department of Astrophysics, The University of Vienna, Vienna, A-1180, Austria
[5] Research Institute of Physics, Southern Federal University, Stachki 194, Rostov-on-Don, 344090, Russia

E-mail contact: dominique.meyer *at* uni-tuebingen.de

The surroundings of massive protostars constitute an accretion disc which has numerically been shown to be subject to fragmentation and responsible for luminous accretion-driven outbursts. Moreover, it is suspected to produce close binary companions which will later strongly influence the star's future evolution in the Hertzsprung-Russel diagram. We present three-dimensional gravitation-radiation-hydrodynamic numerical simulations of 100 $M_\odot$ pre-stellar cores. We find that accretion discs of young massive stars violently fragment without preventing the (highly variable) accretion of gaseous clumps onto the protostars. While acquiring the characteristics of a nascent low-mass companion, some disc fragments migrate onto the central massive protostar with dynamical properties showing that its final Keplerian orbit is close enough to constitute a close massive proto-binary system, having a young high-mass and a low-mass component. We conclude on the viability of the disc fragmentation channel for the formation of such short-period binaries, and that both processes -close massive binary formation and accretion bursts- may happen at the same time. FU-Orionis-type bursts, such as observed in the young high-mass star S255IR-NIRS3, may not only indicate ongoing disc fragmentation, but also be considered as a tracer for the formation of close massive binaries - progenitors of the subsequent massive spectroscopic binaries - once the high-mass component of the system will enter the main-sequence phase of its evolution. Finally, we investigate the ALMA-observability of the disc fragments.

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The Seahorse Nebula: New views of the filamentary infrared dark cloud G304.74+01.32 from SABOCA, *Herschel*, and *WISE*

Oskari Miettinen[1,2,3]

[1] Avarea Oy, Rautatieläisenkatu 6, FI-00520 Helsinki, Finland
[2] Department of Physics, Faculty of Science, University of Zagreb, Bijenicka cesta 32, HR-10000 Zagreb, Croatia
[3] Department of Physics, P.O. Box 64, FI-00014 University of Helsinki, Finland

E-mail contact: oskari *at* phy.hr

Context. Filamentary molecular clouds, such as many of the infrared dark clouds (IRDCs), can undergo hierarchical fragmentation into substructures (clumps and cores) that can eventually collapse to form stars.
Aims. We aim to determine the occurrence of fragmentation into cores in the clumps of the filamentary IRDC G304.74+01.32 (hereafter, G304.74). We also aim to determine the basic physical characteristics (e.g. mass, density, and young stellar object (YSO) content) of the clumps and cores in G304.74.
Methods. We mapped the G304.74 filament at 350 μm using the SABOCA bolometer. The new SABOCA data have a factor of 2.2 times higher resolution than our previous LABOCA 870 μm map of the cloud ($9''$ versus $19''.86$). We also employed the *Herschel* far-infrared (IR) and submillimetre, and *Wide-field Infrared Survey Explorer* (*WISE*) IR imaging data available for G304.74. The *WISE* data allowed us to trace the IR emission of the YSOs associated with the cloud.
Results. The SABOCA 350 μm data show that G304.74 is composed of a dense filamentary structure with a mean

width of only 0.18 ± 0.05 pc. The percentage of LABOCA clumps that are found to be fragmented into SABOCA cores is $36\% \pm 16\%$, but the irregular morphology of some of the cores suggests that this multiplicity fraction could be higher. The *WISE* data suggest that $65\% \pm 18\%$ of the SABOCA cores host YSOs. The mean dust temperature of the clumps, derived by comparing the *Herschel* 250, 350, and 500 μm flux densities, was found to be 15.0 ± 0.8 K. The mean mass, beam-averaged H_2 column density, and H_2 number density of the LABOCA clumps are estimated to be 55 ± 10 $M_\odot$, $(2.0 \pm 0.2) \times 10^{22}$ cm^{-2}, and $(3.1 \pm 0.2) \times 10^4$ cm^{-3}. The corresponding values for the SABOCA cores are 29 ± 3 $M_\odot$, $(2.9 \pm 0.3) \times 10^{22}$ cm^{-2}, and $(7.9 \pm 1.2) \times 10^4$ cm^{-3}. The G304.74 filament is estimated to be thermally supercritical by a factor of $\gtrsim 3.5$ on the scale probed by LABOCA, and by a factor of $\gtrsim 1.5$ for the SABOCA filament.
Conclusions. Our data strongly suggest that the IRDC G304.74 has undergone hierarchical fragmentation. On the scale where the clumps have fragmented into cores, the process can be explained in terms of gravitational Jeans instability. Besides the filament being fragmented, the finding of embedded YSOs in G304.74 indicates its thermally supercritical state, although the potential non-thermal (turbulent) motions can render the cloud a virial equilibrium system on scale traced by LABOCA. The IRDC G304.74 has a seahorse-like morphology in the *Herschel* images, and the filament appears to be attached by elongated, perpendicular striations. This is potentially evidence that G304.74 is still accreting mass from the surrounding medium, and the accretion process can contribute to the dynamical evolution of the main filament. One of the clumps in G304.74, IRAS 13039-6108, is already known to be associated with high-mass star formation, but the remaining clumps and cores in this filament might preferentially form low and intermediate-mass stars owing to their mass reservoirs and sizes. Besides the presence of perpendicularly oriented, dusty striations and potential embedded intermediate-mass YSOs, G304.74 is a relatively nearby ($d \sim 2.5$ kpc) IRDC, which makes it a useful target for future star formation studies. Owing to its observed morphology, we propose that G304.74 could be nicknamed the Seahorse Nebula.

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A Face-on Accretion System in High-Mass Star-Formation: Possible Dusty Infall Streams within 100 AU

Kazuhito Motogi[1], Tomoya Hirota[2,3], Kazuo Sorai[4,5], Yoshinori Yonekura[6], Koichiro Sugiyama[2], Mareki Honma[7,3], Kotaro Niinuma[1], Kazuya Hachisuka[7], Kenta Fujisawa[8] and Andrew J. Walsh[9]

[1] Graduate School of Sciences and Technology for Innovation,Yamaguchi University, Yoshida 1677-1, Yamaguchi 753-8512, Japan

[2] Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan

[3] Department of Astronomical Sciences, SOKENDAI (The Graduate University for Advanced Studies), Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan

[4] Department of Physics, Faculty of Science, Hokkaido University, Sapporo 060-0810, Japan

[5] Department of Cosmosciences, Graduate School of Science, Hokkaido University, Sapporo 060-0810, Japan

[6] Center for Astronomy, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan

[7] Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Hoshigaoka 2-12, Mizusawa, Oshu, Iwate 023-0861, Japan

[8] The Research Institute for Time Studies, Yamaguchi University, Yoshida 1677-1, Yamaguchi 753-8511, Japan

[9] International Centre for Radio Astronomy Research, Curtin University, Bentley, WA 6102, Australia

E-mail contact: kmotogi *at* yamaguchi-u.ac.jp

We report on interferometric observations of a face-on accretion system around the High-Mass young stellar object, G353.273+0.641. The innermost accretion system of 100 au radius was resolved in a 45 GHz continuum image taken with the Jansky-Very Large Array. Our spectral energy distribution analysis indicated that the continuum could be explained by optically thick dust emission. The total mass of the dusty system is $\sim$0.2 $M_\odot$ at minimum and up to a few $M_\odot$ depending on the dust parameters. 6.7 GHz CH_3OH masers associated with the same system were also observed with the Australia Telescope Compact Array. The masers showed a spiral-like, non-axisymmetric distribution with a systematic velocity gradient. The line-of-sight velocity field is explained by an infall motion along a parabolic streamline that falls onto the equatorial plane of the face-on system. The streamline is quasi-radial and reaches the equatorial plane at a radius of 16 au. This is clearly smaller than that of typical accretion disks in High-Mass

star formation, indicating that the initial angular momentum was very small, or the CH_3OH masers selectively trace accreting material that has small angular momentum. In the former case, the initial specific angular momentum is estimated to be $8 \times 10^{20} (M_\star/10\ M_\odot)^{0.5}$ cm^2 s^{-1}, or a significant fraction of the initial angular momentum was removed outside of 100 au. The physical origin of such a streamline is still an open question and will be constrained by the higher-resolution (∼10 mas) thermal continuum and line observations with ALMA long baselines.

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The Effects of Protostellar Jet Feedback on Turbulent Collapse

Daniel Murray[1], Shivam Goyal[2], and Philip Chang[1]

[1] Department of Physics, University of Wisconsin-Milwaukee, 3135 North Maryland Ave., Milwaukee, WI 53211, USA
[2] Department of Physics and Astronomy, Dartmouth College, 6127 Wilder Laboratory, Hanover, NH 03755-3528, USA

E-mail contact: dwmurray *at* uwm.edu

We present results of hydrodynamic simulations of massive star forming regions with and without protostellar jets. We show that jets change the normalization of the stellar mass accretion rate, but do not strongly affect the dynamics of star formation. In particular, $M(t) \propto f^2(t-t)^2$ where $f = 1 - f_{\rm jet}$ is the fraction of mass accreted onto the protostar, $f_{\rm jet}$ is the fraction ejected by the jet, and $(t-t)^2$ is the time elapsed since the formation of the first star. The star formation efficiency is nonlinear in time. We find that jets have only a small effect (of order 25%) on the accretion rate onto the protostellar disk (the "raw" accretion rate). We show that the small scale structure – the radial density, velocity, and mass accretion profiles are very similar in the jet and no-jet cases. Finally, we show that the inclusion of jets does drive turbulence but only on small (parsec) scales.

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Planet population synthesis driven by pebble accretion in cluster environments

N. Ndugu[1], B. Bitsch[2], E. Jurua[1]

[1] Department of Physics, Mbarara University of Science and Technology, Mbarara, Uganda
[2] Lund Observatory, Department of Astronomy and Theoretical Physics, Lund University, 22100 Lund, Sweden

E-mail contact: ndugu.nelson89 *at* gmail.com

The evolution of protoplanetary discs embedded in stellar clusters depends on the age and the stellar density in which they are embedded. Stellar clusters of young age and high stellar surface density destroy protoplanetary discs by external photoevaporation and stellar encounters. Here we consider the effect of background heating from newly formed stellar clusters on the structure of protoplanetary discs and how it affects the formation of planets in these discs. Our planet formation model is build on the core accretion scenario including pebble accretion. We synthesize planet populations that we compare to observations. The giant planets in our simulations migrate over large distances due to the fast type-II migration regime induced by a high disc viscosity ($\alpha = 5.4 \times 10^{-3}$). Cold Jupiters ($r > 1$ AU) originate preferably from the outer disc, while hot Jupiters ($r < 0.1$ AU) preferably form in the inner disc. We find that the formation of gas giants via pebble accretion is in agreement with the metallicity correlation, meaning that more gas giants are formed at larger metallicity. However, our synthetic population of isolated stars host a significant amount of giant planets even at low metallicity, in contradiction to observations where giant planets are preferably found around high metallicity stars, indicating that pebble accretion is very efficient in the standard pebble accretion framework. On the other hand, discs around stars embedded in cluster environments hardly form any giant planets at low metallicity in agreement with observations, where these changes originate from the increased temperature in the outer parts of the disc, which prolongs the core accretion time-scale of the planet. We therefore conclude that the outer disc structure and the planet's formation location determines the giant planet occurrence rate and the formation efficiency of cold and hot Jupiters.

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Connection between jets, winds and accretion in T Tauri stars: The X-shooter view

Brunella Nisini[1], Simone Antoniucci[1], Juan M. Alcalá[2], Teresa Giannini[1], Carlo F. Manara[3], Antonella Natta[4,5], Davide Fedele[4] and Katia Biazzo[6]

[1] INAF - Osservatorio Astronomico di Roma, Italy
[2] INAF - Osservatorio Astronomico di Capodimonte, Italy
[3] Scientific Support Office, Directorate of Science, ESA/ESTEC
[4] INAF - Osservatorio Astrofisico of Arcetri, Italy
[5] DIAS/School of Cosmic Physics, Dublin Institute for Advanced Studies, Ireland
[6] INAF-Osservatorio Astrofisico di Catania, Italy

E-mail contact: nisini *at* oa-roma.inaf.it

Mass loss from jets and winds is a key ingredient in the evolution of accretion discs in young stars. While slow winds have been recently extensively studied in T Tauri stars, little investigation has been devoted on the occurrence of high velocity jets and on how the two mass-loss phenomena are connected with each other, and with the disc mass accretion rates. In this framework, we have analysed the [OI]6300Å line in a sample of 131 young stars with discs in the Lupus, Chamaeleon and σ Orionis star forming regions. The stars were observed with the X-shooter spectrograph at the Very Large Telescope (VLT) and have mass accretion rates spanning from 10^{-12} to 10^{-7} $M_\odot\,yr^{-1}$. The line profile was deconvolved into a low velocity component (LVC) and a high velocity component (HVC), originating from slow winds and high velocity jets, respectively. The LVC is by far the most frequent component, with a detection rate of 77%, while only 30% of sources have a HVC. The fraction of HVC detections slightly increases (i.e. 39%) in the sub-sample of stronger accretors (i.e. with log $(L_{\rm acc}/L_\odot) > -3$). The [OI]6300Å luminosity of both the LVC and HVC, when detected, correlates with stellar and accretion parameters of the central sources (i.e. L_*, M_*, $L_{\rm acc}$, $\dot{M}_{acc}$), with similar slopes for the two components. The line luminosity correlates better (i.e. has a lower dispersion) with the accretion luminosity than with the stellar luminosity or stellar mass. We suggest that accretion is the main drivers for the line excitation and that MHD disc-winds are at the origin of both components. In the sub-sample of Lupus sources observed with ALMA a relationship is found between the HVC peak velocity and the outer disc inclination angle, as expected if the HVC traces jets ejected perpendicularly to the disc plane. Mass ejection rates ($\dot{M}_{jet}$) measured from the detected HVC [OI]6300Å line luminosity span from $\sim 10^{-13}$ to $\sim 10^{-7}$ $M_\odot\,yr^{-1}$. The corresponding $\dot{M}_{jet}/\dot{M}_{acc}$ ratio ranges from ~0.01 to ~0.5, with an average value of 0.07. However, considering the upper limits on the HVC, we infer a $\dot{M}_{jet}/\dot{M}_{acc}$ ratio < 0.03 in more than 40% of sources. We argue that most of these sources might lack the physical conditions needed for an efficient magneto-centrifugal acceleration in the star-disc interaction region. Systematic observations of populations of younger stars, that is, class 0/I, are needed to explore how the frequency and role of jets evolve during the pre-main sequence phase. This will be possible in the near future thanks to space facilities such as the James Webb space telescope (JWST).

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Direct mapping of the temperature and velocity gradients in discs. Imaging the vertical CO snow line around IM Lupi

C. Pinte[1,2,3], F. Ménard[1], G. Duchêne[4,1], T. Hill[5], W.R.F. Dent[5], P. Woitke[6], S. Maret[1], G. van der Plas[1], A. Hales[5,7], I. Kamp[8], W.F. Thi[9], I. de Gregorio-Monsalvo[5], C. Rab[8], S.P. Quanz[10], H. Avenhaus[11], A. Carmona[12], and S. Casassus[11]

[1] Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France
[2] UMI-FCA, CNRS/INSU, France (UMI 3386), and Dept. de Astronomía, Universidad de Chile, Santiago, Chile
[3] Monash Centre for Astrophysics (MoCA) and School of Physics and Astronomy, Monash University, Clayton Vic 3800, Australia
[4] Astronomy Department, University of California, Berkeley CA 94720-3411, USA
[5] Atacama Large Millimeter / Submillimeter Array, Joint ALMA Observatory, Alonso de Córdova 3107, Vitacura 763-0355, Santiago, Chile
[6] Centre for Exoplanet Science, SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, Fife, KY16 9SS, UK
[7] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, Virginia, 22903-2475, United States

[8] Kapteyn Astronomical Institute, University of Groningen, Postbus 800, 9700 AV Groningen, The Netherlands
[9] Max Planck Institute for Extraterrestrial Physics, Giessenbachstrasse, 85741 Garching, Germany
[10] Institute for Astronomy, ETH Zurich, Wolfgang-Pauli-Strasse 27, 8093 Zurich, Switzerland
[11] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile
[12] IRAP, Université de Toulouse, CNRS, UPS, Toulouse, France

E-mail contact: christophe.pinte *at* univ-grenoble-alpes.fr

Accurate measurements of the physical structure of protoplanetary discs are critical inputs for planet formation models. These constraints are traditionally established via complex modelling of continuum and line observations. Instead, we present an empirical framework to locate the CO isotopologue emitting surfaces from high spectral and spatial resolution ALMA observations. We apply this framework to the disc surrounding IM Lupi, where we report the first direct, i.e. model independent, measurements of the radial and vertical gradients of temperature and velocity in a protoplanetary disc. The measured disc structure is consistent with an irradiated self-similar disc structure, where the temperature increases and the velocity decreases towards the disc surface. We also directly map the vertical CO snow line, which is located at about one gas scale height at radii between 150 and 300 au, with a CO freeze-out temperature of 21±2 K. In the outer disc (>300 au), where the gas surface density transitions from a power law to an exponential taper, the velocity rotation field becomes significantly sub-Keplerian, in agreement with the expected steeper pressure gradient. The sub-Keplerian velocities should result in a very efficient inward migration of large dust grains, explaining the lack of millimetre continuum emission outside of 300 au. The sub-Keplerian motions may also be the signature of the base of an externally irradiated photo-evaporative wind. In the same outer region, the measured CO temperature above the snow line decreases to ≈ 15 K because of the reduced gas density, which can result in a lower CO freeze-out temperature, photo-desorption, or deviations from local thermodynamic equilibrium.

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Far-infrared to millimeter data of protoplanetary disks: dust growth in the Taurus, Ophiuchus, and Chamaeleon I star-forming regions

Álvaro Ribas[1], Catherine C. Espaillat[1], Enrique Macías[1], Hervé Bouy[2], Sean Andrews[3], Nuria Calvet[4], David A. Naylor[5], Pablo Riviere-Marichalar[6], Matthijs H.D. van der Wiel[5,7], and David Wilner[3]

[1] Department of Astronomy, Boston University, Boston, MA 02215, USA
[2] Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux, CNRS, F-33615 Pessac, France
[3] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 91023 USA
[4] Astronomy Department, University of Michigan, Ann Arbor, MI 48109, USA
[5] Institute for Space Imaging Science, Department of Physics & Astronomy, University of Lethbridge, Canada
[6] Inst. de Ciencia de Materiales de Madrid. Calle Sor Juana Inés de la Cruz 3, E-28049 Cantoblanco, Madrid, Spain
[7] ASTRON, the Netherlands Institute for Radio Astronomy, PO Box 2, 7990AA Dwingeloo, The Netherlands

E-mail contact: aribas *at* bu.edu

Far-infrared and (sub)millimeter fluxes can be used to study dust in protoplanetary disks, the building blocks of planets. Here, we combine observations from the Herschel Space Observatory with ancillary data of 284 protoplanetary disks in the Taurus, Chamaeleon I, and Ophiuchus star-forming regions, covering from the optical to mm/cm wavelengths. We analyze their spectral indices as a function of wavelength and determine their (sub)millimeter slopes when possible. Most disks display observational evidence of grain growth, in agreement with previous studies. No correlation is found between other tracers of disk evolution and the millimeter spectral indices. A simple disk model is used to fit these sources, and we derive posterior distributions for the optical depth at 1.3 mm and 10 au, the disk temperature at this same radius, and the dust opacity spectral index. We find the fluxes at 70 μm to correlate strongly with disk temperatures at 10 au, as derived from these simple models. We find tentative evidence for spectral indices in Chamaeleon I being steeper than those of disks in Taurus/Ophiuchus, although more millimeter observations are needed to confirm this trend and identify its possible origin. Additionally, we determine the median spectral energy distribution of each region and find them to be similar across the entire wavelength range studied, possibly due to the large scatter in disk properties and morphologies.

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A Molecular-Line Study of the Interstellar Bullet Engine IRAS05506+2414

Raghvendra Sahai[1], Chin-Fei Lee[2], Carmen Sánchez Contreras[3], Nimesh Patel[4], Mark Morris[5] and Mark Claussen[6]

[1] Jet Propulsion Laboratory, MS 183-900, Caltech, Pasadena, CA 91109, USA
[2] Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 106, Taiwan
[3] Dpto. de Astrofísica Molecular e Infraroja, Instituto de Estructura de la Materia-CSIC, Serrano 121, Madrid, Spain
[4] Harvard-Smithsonian Center for Astrophysics, Cambridge, USA
[5] Division of Astronomy & Astrophysics, UCLA, Los Angeles, CA 90095-1547, USA
[6] National Radio Astronomy Observatory, 1003 Lopezville Road, Socorro, NM 87801, USA

E-mail contact: sahai *at* jpl.nasa.gov

We present interferometric and single-dish molecular line observations of the interstellar bullet-outflow source IRAS05506+2414, whose wide-angle bullet spray is similar to the Orion BN/KL explosive outflow and likely arises from an entirely different mechanism than the classical accretion-disk-driven bipolar flows in young stellar objects. The bullet-outflow source is associated with a large pseudo-disk and three molecular outflows – a high-velocity outflow (HVO), a medium-velocity outflow (MVO), and a slow, extended outflow (SEO). The size (mass) of the pseudo-disk is 10,350 AU×6,400 AU (0.64–0.17 $M_\odot$); from a model-fit assuming infall and rotation we derive a central stellar mass of 8–19 $M_\odot$. The HVO (MVO) has an angular size $\sim$ 5180 ($\sim$ 3330) AU, and a projected outflow velocity of $\sim 140\,\mathrm{km\,s^{-1}}$ ($\sim 30\,\mathrm{km\,s^{-1}}$). The SEO size (outflow speed) is $\sim 0.9\,pc$ ($\sim 6\,\mathrm{km\,s^{-1}}$). The HVO's axis is aligned with (orthogonal to) that of the SEO (pseudo-disk). The velocity structure of the MVO is unresolved. The scalar momenta in the HVO and SEO are very similar, suggesting that the SEO has resulted from the HVO interacting with ambient cloud material. The bullet spray shares a common axis with the pseudo-disk, and has an age comparable to that of MVO (few hundred years), suggesting that these three structures are intimately linked together. We discuss several models for the outflows in IRAS 05506+2414 (including dynamical decay of a stellar cluster, chance encounter of a runaway star with a dense cloud, and close passage of two protostars), and conclude that 2nd-epoch imaging to derive proper motions of the bullets and nearby stars can help to discriminate between them.

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Slingshot Mechanism for Clusters: Gas Density Regulates Star Density in the Orion Nebula Cluster (M42)

Amelia M. Stutz[1]

[1] Departmento de Astronom?a, Universidad de Concepci?on, Casilla 160-C, Concepcio?n, Chile

E-mail contact: astutz *at* astro-udec.cl

We characterize the stellar and gas volume density, potential, and gravitational field profiles in the central $\sim$0.5 pc of the Orion Nebula Cluster (ONC), the nearest embedded star cluster (or rather, proto-cluster) hosting massive star formation available for detailed observational scrutiny. We find that the stellar volume density is well characterized by a Plummer profile $\rho_{stars}(\mathrm{r}) = 5755\,M_\odot\,pc^{-3}\,(1+(\mathrm{r/a})^2)^{-5/2}$, where $a = 0.36$ pc. The gas density follows a cylindrical power law $\rho_{gas}(\mathrm{R}) = 25.9\,M_\odot/pc^3\,(\mathrm{R}/pc)^{-1.775}$. The stellar density profile dominates over the gas density profile inside $r \sim 1$ pc. The gravitational field is gas-dominated at all radii, but the contribution to the total field by the stars is nearly equal to that of the gas at $r \sim a$. This fact alone demonstrates that the proto-cluster cannot be considered a gas-free system or a virialized system dominated by its own gravity. The stellar proto-cluster core is dynamically young, with an age of $\sim$2-3 Myr, a 1D velocity dispersion of $\sigma_{\rm obs} = 2.6$ km s^{-1}, and a crossing time of $\sim$0.55 Myr. This timescale is almost identical to the gas filament oscillation timescale estimated recently by Stutz & Gould (2016). This provides strong evidence that the proto-cluster structure is regulated by the gas filament. The proto-cluster structure may be set by tidal forces due to the oscillating filamentary gas potential. Such forces could naturally suppress low density stellar structures on scales $\gtrsim a$. The analysis presented here leads to a new suggestion that clusters form by an analog of the "slingshot mechanism" previously proposed for stars.

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Monitoring observations of 6.7 GHz methanol masers

M. Szymczak[1], M. Olech[1], R. Sarniak[1], P. Wolak[1] and A. Bartkiewicz[1]

[1] Centre for Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland

E-mail contact: msz *at* astro.umk.pl

We report results of 6.7 GHz methanol maser monitoring of 139 star-forming sites with the Torun 32 m radio telescope from June 2009 to February 2013. The targets were observed at least once a month, with higher cadences of 2-4 measurements per week for circumpolar objects. Nearly 80 per cent of the sources display variability greater than 10 per cent on a time-scale between a week and a few years but about three quarters of the sample have only 1-3 spectral features which vary significantly. Irregular intensity fluctuation is the dominant type of variability and only nine objects show evidence for cyclic variations with periods of 120 to 416 d. Synchronised and anti-correlated variations of maser features are detected in four sources with a disc-like morphology. Rapid and high amplitude bursts of individual features are seen on 3-5 occasions in five sources. Long (>50 d to 20 months) lasting bursts are observed mostly for individual or groups of features in 19 sources and only one source experienced a remarkable global flare. A few flaring features display a strong anti-correlation between intensity and line-width that is expected for unsaturated amplification. There is a weak anti-correlation between the maser feature luminosity and variability measure, i.e. maser features with low luminosity tend to be more variable than those with high luminosity. The analysis of the spectral energy distribution and continuum radio emission reveals that the variability of the maser features increases when the bolometric luminosity and Lyman flux of the exciting object decreases. Our results support the concept of a major role for infrared pumping photons in triggering outburst activity of maser emission.

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Outflow-Confined HII regions. II. The Early Break-Out Phase

Kei E. I. Tanaka[1], Jonathan C. Tan[1], Jan E. Staff[2] and Yichen Zhang[3]

[1] University of Florida, USA
[2] University of Virgin Islands, USVI
[3] RIKEN, Japan

E-mail contact: ktanaka *at* ufl.edu

In this series of papers, we model the formation and evolution of the photoionized region and its observational signatures during massive star formation. Here we focus on the early break out of the photoionized region into the outflow cavity. Using results of 3-D magnetohydrodynamic-outflow simulations and protostellar evolution calculations, we perform post-processing radiative-transfer. The photoionized region first appears at a protostellar mass of $m_* = 10 M_\odot$ in our fiducial model, and is confined to within 10–100 AU by the dense inner outflow, similar to some observed very small hyper compact HII regions. Since the ionizing luminosity of the massive protostar increases dramatically as Kelvin-Helmholz (KH) contraction proceeds, the photoionized region breaks out to the entire outflow region in $\lesssim$10,000 yr. Accordingly, the radio free-free emission brightens significantly in this stage. In our fiducial model, the radio luminosity at 10 GHz changes from 0.1 mJy kpc^2 at $m_* = 11 M_\odot$ to 100 mJy kpc^2 at $m_* = 16 M_\odot$, while the infrared luminosity increases by less than a factor of two. The radio spectral index also changes in the break-out phase from the optically thick value of ~ 2 to the partially optically thin value of ~ 0.6. Additionally, we demonstrate that short-timescale variation in free-free flux would be induced by an accretion burst. The outflow density is enhanced in the accretion burst phase, which leads to a smaller ionized region and weaker free-free emission. The radio luminosity may decrease by one order of magnitude during such bursts, while the infrared luminosity is much less affected, since internal protostellar luminosity dominates over accretion luminosity after KH contraction starts. Such variability may be observable on timescales as short 10–100 yr, if accretion bursts are driven by disk instabilities.

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Cloudless atmospheres for young low-gravity substellar objects

P. Tremblin[1], G. Chabrier[2,3], I. Baraffe[2,3], Michael. C. Liu[4], E.A. Magnier[4], P.-O. Lagage[6,7], C. Alves de Oliveira[8], A.J. Burgasser[9], D.S. Amundsen[10,11], B. Drummond[2]

[1] Maison de la Simulation, CEA, CNRS, Univ. Paris-Sud, UVSQ, Université Paris-Saclay, Gif-sur-Yvette, France
[2] Astrophysics Group, University of Exeter, EX4 4QL Exeter, UK
[3] Ecole Normale Supérieure de Lyon, CRAL, UMR CNRS 5574, 69364 Lyon Cedex 07, France
[4] Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[6] Irfu, CEA, Université Paris-Saclay, F-9119 Gif-sur Yvette, France
[7] Université Paris Diderot, AIM, Sorbonne Paris Cité, CEA, CNRS, F-91191 Gif-sur-Yvette, France
[8] European Space Agency, c/o STScI, 3700 San Martin Drive, Baltimore, MD 21218, USA
[9] UC San Diego, M/C 0424, 9500 Gilman Drive, La Jolla, CA 92093, USA
[10] Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY 10025, USA
[11] NASA Goddard Institute for Space Studies, New York, NY 10025, USA

E-mail contact: pascal.tremblin *at* cea.fr

Atmospheric modeling of low-gravity (VL-G) young brown dwarfs remains a challenge. The presence of very thick clouds has been suggested because of their extremely red near-infrared (NIR) spectra, but no cloud models provide a good fit to the data with a radius compatible with evolutionary models for these objects. We show that cloudless atmospheres assuming a temperature gradient reduction caused by fingering convection provides a very good model to match the observed VL-G NIR spectra. The sequence of extremely red colors in the NIR for atmospheres with effective temperature from ∼2000 K down to ∼1200 K is very well reproduced with predicted radii typical of young low-gravity objects. Future observations with NIRSPEC and MIRI on the James Webb Space Telescope (JWST) will provide more constrains in the mid-infrared, helping to confirm/refute whether or not the NIR reddening is caused by fingering convection. We suggest that the presence/absence of clouds will be directly determined by the silicate absorption features that can be observed with MIRI. JWST will therefore be able to better characterize the atmosphere of these hot young brown dwarfs and their low-gravity exoplanet analogues.

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Optical Polarimetric and Near-Infrared Photometric Study of the RCW95 Galactic HII Region

Jaime Vargas-Gonzlez[1], Alexandre Roman-Lopes[1], F. P. Santos[2], G. A. P. Franco[3], J. F. C. Santos Jr.[3], F. F. S. Maia[3] and David Sanmartim[4]

[1] Departamento de Fisica - Universidad de La Serena, Cisternas 1200, La Serena, Chile
[2] Physics & Astronomy Department-CIERA, Northwestern University, Evanston, USA
[3] Departamento de Fisica, ICEx, Universidade Federal de Minas Gerais, Av. Antonio Carlos 6627, 31270-901 Belo Horizonte, MG, Brazil
[4] Gemini Observatory, Casilla 603, La Serena, Chile

E-mail contact: jvargas *at* dfuls.cl

We carried out an optical polarimetric study in the direction of the RCW 95 star forming region in order to probe the sky-projected magnetic field structure by using the distribution of linear polarization segments which seem to be well aligned with the more extended cloud component. A mean polarization angle of $\theta = 49.8° \pm 7.7°$ was derived. Through the spectral dependence analysis of polarization it was possible to obtain the total-to-selective extinction ratio (R_V) by fitting the Serkowski function, resulting in a mean value of $R_V = 2.93 \pm 0.47$. The foreground polarization component was estimated and is in agreement with previous studies in this direction of the Galaxy. Further, near-infrared images from Vista Variables in the Via Lactea (VVV) survey were collected to improve the study of the stellar population associated with the HII region. The Automated Stellar Cluster Analysis (ASteCA) algorithm was employed to derive structural parameters for two clusters in the region, and a set of PAdova and TRieste Stellar Evolution Code (PARSEC) isochrones was superimposed on the decontaminated colour-magnitude diagrams (CMDs) to estimate an age of about 3 Myr for both clusters. Finally, from the near-infrared photometry study combined with spectra obtained with the Ohio State Infrared Imager and Spectrometer (OSIRIS) mounted at the Southern

Astrophysics Research Telescope (SOAR) we derived the spectral classification of the main ionizing sources in the clusters associated with IRAS 15408-5356 and IRAS 15412-5359, both objects classified as O4 V stars.

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Proper motions of L1551 IRS 5 binary system using 7 mm VLA observations

A.M. Villa[1], M.A. Trinidad[1,3], E. de la Fuente[2,3] and T. Rodríguez-Esnard[2]

[1] Departamento de Astronomía,Universidad de Guanajuato, México

[2] Departamento de Fisica, Universidad de Guadalajara, México

[3] Corresponding author

E-mail contact: trinidad *at* astro.ugto.mx

We analyzed high angular resolution observations of the Very Large Array archive at a wavelength of 7 mm of the L1551 IRS 5 binary system. Six sets of observations,five with the A configuration and one with the B configuration, were used, covering a time span of about 15 years. With these multi-epoch data, we estimated the absolute and relative proper motions of the binary system, which are about 25.1 mas yr^{-1} ($\sim$16.7 km s^{-1} considering a distance of 140 pc) and 4.2 mas yr^{-1}, respectively. Finally, based on the relative proper motion, we estimated a total mass of the L1551 IRS 5 binary system of 1.7 $M_{\odot}$ and an orbital period of 246 years.

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A revised estimate of the distance to the clouds in the Chamaeleon complex using the Tycho-Gaia Astrometric Solution

Jordan Voirin[1], Carlo F. Manara[1,2], and Timo Prusti[1]

[1] Scientific Support Office, Directorate of Science, European Space Research and Technology Center (ESA/ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands

[2] ESA Research Fellow; Current address: European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany

E-mail contact: jordan.voirin *at* gmail.com

The determination of the distance to dark star-forming clouds is a key parameter to derive the properties of the cloud itself, and of its stellar content. This parameter is still loosely constrained even in nearby star-forming regions. We want to determine the distances to the clouds in the Chamaeleon-Musca complex and to explore the connection between these clouds and the large scale cloud structures in the galaxy. We use the newly estimated distances obtained from the parallaxes measured by the Gaia satellite and included in the Tycho-Gaia Astrometric Solution catalog. When known members of a region are included in this catalog we use their parallaxes to infer the distance to the cloud. Otherwise, we analyze the dependence of the color excess on the distance of the stars and look for a turn-on of this excess, which is a proxy of the position of the front-edge of the star-forming cloud. We are able to measure the distance to the three Chamaeleon clouds. The distance to Chamaeleon I is 179 pc, 20 pc further away than previously assumed. The Chamaeleon II cloud is located at the distance of 181 pc, which agrees with previous estimates. We are able to measure for the first time a distance to the Chamaeleon III cloud of 199 pc. Finally, the distance of the Musca cloud is smaller than 603 pc. These estimates do not allow us to distinguish between the possibility that the Chamaeleon clouds are part of a sheet of clouds parallel to the galactic plane, or perpendicular to it. Gaia Data Release 2 will allow us to put more stringent constraints on the distances to these clouds by giving us access to parallax measurements for a larger number of members of these regions.

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Variability of the Lowest Mass Objects in the AB Doradus Moving Group

Johanna M. Vos[1,2], Katelyn N. Allers[3], Beth A. Biller[1,2], Michael C. Liu[4], Trent J. Dupuy[5], Jack F. Gallimore[3], Dunni Adenuga[3] and William M.J. Best[4]

[1] SUPA Institute for Astronomy, University of Edinburgh, Blackford Hill View, Edinburgh EH9 3HJ, UK
[2] Centre for Exoplanet Science, University of Edinburgh, UK
[3] Department of Physics and Astronomy, Bucknell University, Lewisburg, PA 17837, USA
[4] Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[5] The University of Texas at Austin, Department of Astronomy, 2515 Speedway C1400, Austin, TX 78712, USA

E-mail contact: jvos *at* roe.ac.uk

We present the detection of [3.6 μm] photometric variability in two young, L/T transition brown dwarfs, WISE J004701.06+680352.1 (W0047) and 2MASS J2244316+204343 (2M2244) using the *Spitzer Space Telescope*. We find a period of 16.4±0.2 hr and a peak-to-peak amplitude of 1.07±0.04% for W0047, and a period of 11±2 hr and amplitude of 0.8±0.2% for 2M2244. This period is significantly longer than that measured previously during a shorter observation. We additionally detect significant *J*-band variability in 2M2244 using the Wide-Field Camera on UKIRT. We determine the radial and rotational velocities of both objects using Keck NIRSPEC data. We find a radial velocity of $-16.0^{+0.8}_{-0.9}$ km s^{-1} for 2M2244, and confirm it as a bona fide member of the AB Doradus moving group. We find rotational velocities of $v \sin i = 9.8 \pm 0.3$ km s^{-1}and $14.3^{+1.4}_{-1.5}$ km s^{-1} for W0047 and 2M2244, respectively. With inclination angles of $85^{+5}_{-9}{}^{\circ}$ and $76^{+14}_{-20}{}^{\circ}$, W0047 and 2M2244 are viewed roughly equator-on. Their remarkably similar colours, spectra and inclinations are consistent with the possibility that viewing angle may influence atmospheric appearance. We additionally present *Spitzer* [4.5 μm] monitoring of the young, T5.5 object SDSS111010+011613 (SDSS1110) where we detect no variability. For periods ¡18 hr, we place an upper limit of 1.25% on the peak-to-peak variability amplitude of SDSS1110.

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An Explanation of the Very Low Radio Flux of Young Planet-mass Companions

Ya-Lin Wu[1], Laird M. Close[1], Josh A. Eisner[1], and Patrick D. Sheehan[2]

[1] Steward Observatory, University of Arizona, Tucson, AZ 85721, USA
[2] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK 73019, USA

E-mail contact: yalinwu *at* email.arizona.edu

We report Atacama Large Millimeter/submillimeter Array (ALMA) 1.3 mm continuum upper limits for 5 planetary-mass companions DH Tau B, CT Cha B, GSC 6214-210 B, 1RXS 1609 B, and GQ Lup B. Our survey, together with other ALMA studies, have yielded null results for disks around young planet-mass companions and placed stringent dust mass upper limits, typically less than 0.1 $M_{\oplus}$, when assuming dust continuum is optically thin. Such low-mass gas/dust content can lead to a disk lifetime estimate (from accretion rates) much shorter than the age of the system. To alleviate this timescale discrepancy, we suggest that disks around wide companions might be very compact and optically thick, in order to sustain a few Myr of accretion yet have very weak (sub)millimeter flux so as to still be elusive to ALMA. Our order-of-magnitude estimate shows that compact optically-thick disks might be smaller than 1000 $R_{\rm jup}$ and only emit $\sim\mu$Jy of flux in the (sub)millimeter, but their average temperature can be higher than that of circumstellar disks. The high disk temperature could impede satellite formation, but it also suggests that mid- to far-infrared might be more favorable than radio wavelengths to characterize disk properties. Finally, the compact disk size might imply that dynamical encounters between the companion and the star, or any other scatterers in the system, play a role in the formation of planetary-mass companions.

Accepted by AJ

http://arxiv.org/pdf/1710.07489

What can the SEDs of first hydrostatic core candidates reveal about their nature?

Alison K. Young[1], Matthew R. Bate[1], Chris F. Mowat[1], Jennifer Hatchell[1] and Tim J. Harries[1]

[1] Physics and Astronomy, University of Exeter, Exeter, EX4 4QL, UK

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

The first hydrostatic core (FHSC) is the first stable object to form in simulations of star formation. This stage has yet to be observed definitively, although several candidate FHSCs have been reported. We have produced synthetic spectral energy distributions (SEDs) from 3D hydrodynamical simulations of pre-stellar cores undergoing gravitational collapse for a variety of initial conditions. Variations in the initial rotation rate, radius and mass lead to differences in the location of the SED peak and far-infrared flux. Secondly, we attempt to fit the SEDs of five FHSC candidates from the literature and five newly identified FHSC candidates located in the Serpens South molecular cloud with simulated SEDs. The most promising FHSC candidates are fitted by a limited number of model SEDs with consistent properties, which suggests the SED can be useful for placing constraints on the age and rotation rate of the source. The sources we consider most likely to be in FHSC phase are B1-bN, CB17-MMS, Aqu-MM1 and Serpens South candidate K242. We were unable to fit SerpS-MM22, Per-Bolo 58 and Chamaeleon-MMS1 with reasonable parameters, which indicates that they are likely to be more evolved.

Accepted by MNRAS

https://arxiv.org/pdf/1710.04432

The Effects of Protostellar Disk Turbulence on CO Emission Lines: A Comparison Study of Disks with Constant CO Abundance vs. Chemically Evolving Disks

Mo Yu[1], Neal J. Evans II[1,2], Sarah E. Dodson-Robinson[3], Karen Willacy[4], and Neal J. Turner[4]

[1] Astronomy Department, University of Texas, 2515 Speedway, Stop C1400, Austin, TX 78712, USA
[2] Korea Astronomy and Space Science Institute, 776, Daedeokdae-ro, Yuseong-gu, Daejeon, 34055, Korea
[3] University of Delaware, Department of Physics and Astronomy, 217 Sharp Lab, Newark, DE 19716
[4] Mail Stop 169-506, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109

E-mail contact: sdr *at* udel.edu

Turbulence is the leading candidate for angular momentum transport in protoplanetary disks and therefore influences disk lifetimes and planet formation timescales. However, the turbulent properties of protoplanetary disks are poorly constrained observationally. Simon et al. (2015) suggested that the ratio of the peak line flux to the flux at line center of the CO J=3–2 transition is a reasonable diagnostic of turbulence, while Flaherty et al. (2015) and Flaherty et al. (2017) found turbulent speeds in HD 163296 smaller than what fully-developed MRI would produce based on the Simon et al. (2015) simulation results. Yet Simon et al. (2015) and Flaherty et al. (2015) assumed a constant CO/H_2 ratio of 0.0001 in locations where CO is not frozen-out or photodissociated. Yu et al. (2016) found that the CO abundance varies both with distance from the star and as a function of time because CO molecules are gradually dissociated, with the liberated carbon forming complex organic molecules that freeze out on grain surfaces. We simulate the emission lines of CO based on chemical evolution models presented in Yu et al. (2016), and find that the peak-to-trough ratio changes as a function of time as CO is destroyed. Specifically, a CO-depleted disk with high turbulent velocity mimics the peak-to-trough ratios of a non-CO-depleted disk with lower turbulent velocity. We suggest that disk observers and modelers take into account the possibility of CO depletion when using line peak-to-trough ratios to constrain the degree of turbulence in disks. Assuming that $CO/H_2 = 0.0001$ at all disk radii can lead to underestimates of turbulent speeds in the disk by at least 0.2 km s^{-1}.

Accepted by ApJ

http://arxiv.org/pdf/1710.03657

Decoupling of Magnetic Fields in Collapsing Protostellar Envelopes and Disc Formation and Fragmentation

Bo Zhao[1], Paola Caselli[1], Zhi-Yun Li[2] and Ruben Krasnopolsky[3]

[1] Max-Planck-Institut für extraterrestrische Physik (MPE), Garching, Germany, 85748
[2] University of Virginia, Astronomy Department, Charlottesville, USA, 22904
[3] Academia Sinica Institute of Astronomy and Astrophysics, 10167, Taipei, Taiwan

E-mail contact: bo.zhao *at* mpe.mpg.de

Efficient magnetic braking is a formidable obstacle to the formation of rotationally supported discs (RSDs) around protostars in magnetized dense cores.We have previously shown, through 2D(axisymmetric) non-ideal MHD simulations, that removing very small grains (VSGs: $\sim$10 Å to few 100 Å) can greatly enhance ambipolar diffusion and enable the formation of RSDs. Here we extend the simulations of disc formation enabled by VSG removal to 3D.We find that the key to this scenario of disc formation is that the drift velocity of the magnetic field almost cancels out the infall velocity of the neutrals in the 10^2-10^3 AU-scale 'pseudo-disc' where the field lines are most severely pinched and most of protostellar envelope mass infall occurs. As a result, the bulk neutral envelope matter can collapse without dragging much magnetic flux into the disc-forming region, which lowers the magnetic braking efficiency. We find that the initial discs enabled by VSG removal tend to be Toomre-unstable, which leads to the formation of prominent spiral structures that function as centrifugal barriers. The piling-up of infall material near the centrifugal barrier often produces dense fragments of tens of Jupiter masses, especially in cores that are not too strongly magnetized. Some fragments accrete onto the central stellar object, producing bursts in mass accretion rate. Others are longer lived, although whether they can survive long-term to produce multiple systems remains to be ascertained. Our results highlight the importance of dust grain evolution in determining the formation and properties of protostellar discs and potentially multiple systems.

Accepted by MNRAS

http://adsabs.harvard.edu/pdf/2017arXiv170606504Z

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Dissertation Abstracts

Dust and Gas in the Cradles of Star Formation

Wanggi Lim

Astronomy Department, University of Florida, USA

211 Bryant Space Science Center, Gainesville, FL 32611, USA

Address as of 4 Dec 2017: SOFIA-USRA, NASA Ames Research Center, MS 232-12, Moffett Field, CA 94035, USA

Electronic mail: wanggi.lim.astro *at* gmail.com

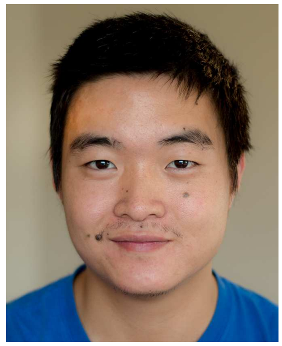
Ph.D dissertation directed by: Jonathan C. Tan

Ph.D degree awarded: August 2017

I investigate how stars form from dense clouds of molecular gas and dust, especially focussing on how we can measure physical properties of these structures. First, I develop methods of Mid- and Far-Infrared extinction (MIREX/FIREX) mapping of infrared dark clouds (IRDCs), utilizing Spitzer and Herschel imaging data. These enable construction of the deepest ever extinction maps, probing cloud structures that may be initial conditions for massive star and star cluster formation. A byproduct of this work is a first study of dust opacity variation with infrared wavelength in these regions, testing models of grain composition and evolution. Second, I extend this dust opacity law investigation by analyzing Spitzer-IRS spectra (15-38μm) of IRDCs to develop a new spectroscopic infrared extinction (SIREX) mapping technique. I find evidence of grain growth and ice mantle formation in high density regions. Third, I develop methods of analyzing sub-mm thermal emission from IRDCs to derive their temperature and mass surface density structures. I compare these maps, including Σ probability distribution functions (PDFs), of a massive IRDC and surrounding giant molecular cloud (GMC) with those derived from extinction mapping. The two Σ-PDFs are consistent, being well fit by a single log-normal, with only a small mass fraction ($\sim$0.03-0.08) in a high-Σ power-law tail, even though gas kinematics indicate the IRDC and GMC are self-gravitating. Fourth, I extend these methods to a larger samples of clouds, including 10 IRDCs. I also analyze molecular line emission from these clouds, especially ^{13}CO (J=1-0). I derive gas phase abundances of ^{13}CO, including spatial variations and dependence on temperature and Σ. This constrains the process of CO freeze-out onto dust grain ice mantles, with important astrochemical implications. The ^{13}CO spectra also yield radial velocity kinematics of the clouds, enabling study of their dynamical state. The internal velocity dispersions of the IRDCs indicate they are gravitationally bound. These studies are foundational for more general investigations of the dynamics of forming clusters across the evolutionary sequence from starless clumps to embedded clusters to young, optically-revealed clusters.

Inside-Out Planet Formation: Pebble Delivery and Planet-disk Co-evolution

Xiao Hu



Thesis work conducted at: Department of Astronomy, University of Florida, USA

Current address: Room 241, BPB Building, Department of Physics and Astronomy, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV, 89154-4002, USA

Electronic mail: xiao.hu.astro at gmail.com

Ph.D dissertation directed by: Jonathan C. Tan

Ph.D degree awarded: August 2017

The *Kepler* mission has discovered more than 4000 exoplanet candidates. Many of them are in systems with tightly packed inner planets (STIPs). Inside-Out Planet Formation (IOPF) (Chatterjee & Tan, 2014) has been proposed as a scenario to explain these systems. It involves sequential *in situ* planet formation at the local pressure maximum of a retreating dead zone inner boundary (DZIB). Pebbles accumulate at this pressure trap, which builds up a pebble ring, and then a planet. The planet is expected to grow in mass until it opens a gap, which helps to both truncate pebble accretion and also induce DZIB retreat that sets the location of formation of the next planet. This simple scenario may be modified if the planet undergoes significant migration from its formation location. Thus planet-disk interactions play a crucial role in the IOPF scenario. We present numerical simulations that firstly assess the disk torqueexerted on the planet in an environment where the disk has steep decrease in its mass surface density in the inner zone. We find the planet does not migrate from this location. We then study gap opening to estimate the masses of planets expected in the IOPF scenario. We present a simple DZIB retreat model based on X-ray penetration, to estimate the location of second planet formation. Next, we build a detailed global pebble evolution model, including radial drift, sweep-up growth and mutual coagulation of pebbles of various sizes and locations, to have a better estimate for the pebble ring formation timescale. We apply this in a new, realistic model of radial disk structure. We carry out a suite of simulations to understand how gap opening depends on IOPF model parameters. Finally, we present results preliminary from numerical simulations of IOPF that including additional physics of pebble dynamics and magnetic fields.

New Jobs

Chalmers Initiative on Cosmic Origins (CICO): Cosmic Origins Postdoctoral Fellowships

CICO has been established in 2017 with the arrival of Prof. Jonathan C. Tan and Asst. Professor Jouni Kainulainen at Chalmers University of Technology (Gothenburg/Onsala, Sweden). CICO has formed strategic international partnerships with the Department of Astronomy at the University of Virginia (Tan group), the Max Planck Institute for Extraterrestrial Physics (MPE) (Caselli group) and the Max Planck Institute for Astronomy (MPIA) (Kainulainen group).

Applications are invited for one or more three-year (2+1) Cosmic Origins postdoctoral fellowships to be hosted at Chalmers. There are also four-year (2+2) fellowship positions to be hosted jointly by Chalmers and MPE (Garching, Germany) and MPIA (Heidelberg, Germany). Application deadlines are 1st December 2017. See

https://jobregister.aas.org/ad/ec101888
https://jobregister.aas.org/ad/3408d39e
https://jobregister.aas.org/ad/1792bbf3

and

http://cosmicorigins.space/ for more information.

Two doctoral students in Astronomy and Astrophysics at Lund Observatory

Research fields of galaxy and planet formation is in rapid development, fuelled by the wealth of new observational data and the advent of more and more powerful supercomputers. Funding has been obtained from the Knut and Alice Wallenberg (KAW) Foundation and the European Research Council (ERC) to hire two PhD students in theoretical and computational astrophysics at Lund Observatory, focusing on planet or galaxy formation.

The PhD students will work within the subjects:

- Planets (w. Anders Johansen): (1) the growth from dust to pebbles in protoplanetary discs, (2) the formation of terrestrial planets, super-Earths and giant planets by accretion of planetesimals and pebbles and (3) the chemical composition of planets.

- Galaxies (w. Oscar Agertz): (1) cosmological simulations of galaxy formation and evolution (2) the formation of stars and star clusters in galaxies across cosmic time (3) impact of feedback processes on galaxy formation.

In addition to working on the topics listed above, the students will work within the inspiring environment at Lund Observatory, which currently hosts 26 scientific staff, including postdocs, and 13 PhD students.

Candidates should send a curriculum vitae and a brief statement of research interest. The application should also include the names, telephone numbers and e-mail addresses of two persons who have agreed to serve as a reference for the applicant. Note that reference letters should not be sent to us in connection with the application; we will contact the reference persons when required.

Applications should be submitted electronically: http://www.astro.lu.se/vacancies/

Included Benefits: All employees in Sweden and at Lund University enjoy full access to the national health care system. The position includes 5 weeks paid annual leave. For employees with small children there are extra possibilities of leave and there are state provided daycare facilities.

Application Deadline: Friday, 1 December, 2017. For inquiries about the job, please email us at:
Anders Johansen: anders@astro.lu.se and Oscar Agertz: oscar.agertz@astro.lu.se

EWASS 2018 Special Session SS5 - Liverpool 3-6 April 2018

Complex organic molecules in the Universe: current understanding and perspectives

One of the key questions in modern Astronomy is how life appeared on Earth. It is currently believed that the link between the chemistry observed in the interstellar medium (ISM) and life on Earth may be Complex Organic Molecules (COMs), carbon-based compounds with more than 6 atoms in their molecular structure. Most of the detections of COMs in the ISM have been reported toward either the central region of our Galaxy, the Galactic Center, or toward the hot molecular cocoons around high-mass and low-mass protostars. As a consequence, it has been traditionally assumed that COMs form on the surface of interstellar dust grains predominantly in hot environments.

In the past decade, new instrumentation has allowed studies of COMs at much higher sensitivity and spectral resolution, and toward a variety of astronomical objects. The results from these studies have shown that COMs are indeed detected not only in hot galactic environments but also in Solar-system objects such as comets, or even in nearby and high-redshift galaxies. Particularly striking is the detection of these complex organics in harsh environments for COM formation such as UV photon-dominated regions (PDRs), molecular outflows, protoplanetary disks, or cold dark cloud cores.

Triggered by these discoveries, the community has made an extraordinary effort to understand the formation of COMs in unfavourable environments. Firstly, large COM surveys have been, or are currently being, carried out at different facilities such as the IRAM 30m telescope, the GBT, NOEMA, and ALMA, to furnish a complete inventory of COMs in star-forming regions at different evolutionary stages and under different physical conditions. Secondly, theoretical studies have proposed new mechanisms for COM formation, including gas-phase formation, non-canonical chemical explosions, cosmic-ray induced radical diffusion, impulsive spot heating of grains, or radical-radical recombination after H-atom addition/abstraction reactions on grain surfaces. Some of these mechanisms are controversial and their actual efficiency is, in most cases, unconstrained. Thirdly, experimental measurements are currently being performed in the lab as a result of these theoretical works, to provide constraints on the efficiency of these mechanisms, but general consensus does not exist yet.

This EWASS Symposium aims at bringing the community together to identify the key limitations in our understanding of COM chemistry and to discuss ideas to overcome those limitations. With the advent of JWST in October 2018, and with ALMA entering its Full Operations phase, this symposium will help us in gaining a complete and detailed view of our current understanding of COM chemistry, and to design the strategy to best exploit these facilities.

Programme:

COM observations: inventory in galaxies, star-forming regions and Solar-system bodies.
COM chemical modelling: Limitations and improvements.
Laboratory experiments of COM formation: Limitations and improvements.

Invited speakers:

Cecilia Ceccarelli (LAOG, France) - Kathrin Altwegg (Bern University, Switzerland) - Rebeca Aladro (MPIfR, Germany) - Catherine Walsh (University of Leeds, UK) - Anton Vasyunin (MPE, Germany) - David Quenard (QMUL, UK) - Harold Linnartz (Leiden Observatory, Netherlands) - Louis D'Hendecourt (Universit d'Aix-Marseille, France) - Nadia Balucani (Universit di Perugia, Italy)

Scientific organisers:

Izaskun Jimenez-Serra (QMUL, UK), Paola Caselli (MPE, Germany), Serena Viti (UCL, UK), Leonardo Testi (ESO, Germany), Jesus Martin-Pintado (CAB, Spain), Marco Minissale (AMU, France)

Contact: Izaskun Jimenez-Serra (i.jimenez-serra @ qmul.ac.uk)

From Prestellar Cores to Solar Nebulae

A six weeks program at Paris-Saclay May 14 - June 22, 2018

Understanding the formation of stars and the formation of planets are both cornerstone challenges in modern astronomy. These highly multi-physics and multi-scale problems are tightly linked through the formation and evolution of proto-planetary discs. As such, they should ideally be apprehended simultaneously. In practice however, due to the great variety of instruments and techniques used as well as the complexity of physical processes involved, this field is traditionally subdivided in several communities addressing specific questions to reach a global understanding.

The Paris-Saclay university is funding a program entitled "From prestellar cores to solar nebulae". The 6-weeks program is subdivided in three 2-weeks sessions, dedicated to the collapse of dense cores and disc formation, late disc evolution, and matter evolution from core to solar nebulae. The main goal of the program is to create links between communities and scientific questions involved in each field: whenever it is possible, we encourage attendants to participate in two of them in order to favor interactions across different research fields.

Unlike typical conferences, the daily schedule is composed of informal talks in the morning and open time for discussion and collaborative work in the rest of the day.

SOC: Emmanuel Dartois, Jean Duprat, Sébastien Fromang, Patrick Hennebelle, Anaëlle Maury & Eric Pantin

Applications are open up to the end of 2017. Interest in the program should be expressed with an email to core2disk@gmail.com to receive further information on the program. There is a limited number of places.

Further information can be found at: https://www.ias.u-psud.fr/core2disk/

Tracing the Flow: Galactic Environments and the Formation of Massive Stars

2-6 July 2018, Lake Windermere, UK

Developing a comprehensive understanding of the varied and complex processes associated with the formation of massive stars requires connecting a wide range of environments and physical size scales from galactic disks down to individual massive sources. Combining large scale surveys of our galactic plane with the sub-arcsecond images in the millimetre and sub-millimetre which ALMA now routinely produces, in principle allow us to map the flow of material from galactic environments through clouds to protostars. Increasingly these observations probe not only the structure and kinematics of regions, but also their chemistry and magnetic fields. Wide field surveys also help to place massive star formation in the wider context of the environment of our galaxy as well as other, more extreme, galaxies.

With the massive increase in spatial dynamic range and the volume of data now becoming available this meeting will provide the opportunity to assess the current state of our knowledge of massive star formation. In addition, it will help identify the key issues for future work and look forward to the expanding opportunities ALMA will continue to offer in the fields of galactic and extragalactic massive star formation as well as those provided by JWST, ELTs, SKA, ngVLA and other facilities in the future.

This meeting is the next in the series of high-mass star formation meetings which have included:

- The Soul of High-Mass Star Formation Conference, 2015
- Great Barriers in High-Mass Star Formation, 2010
- Massive Star Formation: Observations confront Theory, 2007
- Massive Star Birth: A Crossroads of Astrophysics, 2005

Pre-registration is now open.

For further information: http://almaost.jb.man.ac.uk/meetings/TtF

Summary of Upcoming Meetings

Exoplanets and Planet Formation
11 - 15 December 2017, Shang Hai, China
https://indico.leeinst.sjtu.edu.cn/event/25/

Star Formation and Young Stars in Cygnus
31 Jan - 2 Feb 2018, Keele, UK
http://www.astro.keele.ac.uk/cygnus

Magnetic Fields or Turbulence: Which is the critical factor for the formation of stars and planetary disks?
6 - 9 February 2018, Hsinchu, Taiwan
http://events.asiaa.sinica.edu.tw/workshop/20180206/index.php

Water during planet formation and evolution 2018
12-16 February 2018, Zürich, Switzerland
https://waterzurich.github.io/

Star and Planet Formation in the Southwest 2 (SPF2)
12 - 16 March 2018, Oracle, Arizona, USA
http://tinyurl.com/spf2018

Cosmic Rays: the salt of the star formation recipe
2 - 4 May 2018, Florence, Italy
http://www.arcetri.astro.it/cosmicrays

EPoS 2018 The Early Phase of Star Formation - Archetypes
13 - 18 May 2018, Ringberg Castle, Tegernsee, Germany
http://www.mpia.de/homes/stein/EPoS/epos.php

Interstellar: The Matter
14 - 18 May 2018, Cozumel, Mexico
http://bigbang.nucleares.unam.mx/astroplasmas/interstellar-the-matter

From Prestellar Cores to Solar Nebulae
14 May - 22 June 2018, Paris-Saclay, France
https://www.ias.u-psud.fr/core2disk/

The Olympian Symposium 2018: Gas and stars from milli- to mega- parsecs
28 May - 1 June 2018, Mt. Olympus, Greece
http://www.olympiansymposium.org

Tracing the Flow: Galactic Environments and the Formation of Massive Stars
2 - 6 July 2018, Lake Windermere, UK
http://almaost.jb.man.ac.uk/meetings/TtF

Astrochemistry: Past, Present, and Future
10 - 13 July, 2018, Pasadena, USA
http://www.cfa.harvard.edu/events/2018/astrochem18

Cool Stars 20: Cambridge Workshop on Cool Stars, Stellar Systems and the Sun
29 July - 3 August 2018, Cambridge/Boston, USA
http://www.coolstars20.com

The Wonders of Star Formation
3 - 7 September 2018, Edinburgh, Scotland
http://events.ph.ed.ac.uk/star-formation