THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 229 — 27 Jan 2012 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

Abstracts of recently accepted papers

Mechanical Equilibrium of Hot, Large-Scale Magnetic Loops on T Tauri Stars

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The most extended, closed magnetic loops inferred on T Tauri stars confine hot, X-ray emitting plasma at distances from the stellar surface beyond the the X-ray bright corona and closed large-scale field, distances comparable to the corotation radius. Mechanical equilibrium models have shown that dense condensations, or "slingshot prominences", can rise to great heights due to their density and temperatures cooler than their environs. On T Tauri stars, however, we detect plasma at temperatures hotter than the ambient coronal temperature. By previous model results, these loops should not reach the inferred heights of tens of stellar radii where they likely no longer have the support of the external field against magnetic tension. In this work, we consider the effects of a stellar wind and show that indeed, hot loops that are negatively buoyant can attain a mechanical equilibrium at heights above the typical extent of the closed corona and the corotation radius.

Accepted by Monthly Notices of the Royal Astronomical Society

http://www.astro.lsa.umich.edu/~aarnio/preprints/AarnioTTLoops.pdf

Galactic structure based on the ATLASGAL 870 μm survey

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The ATLASGAL 870 μm continuum survey conducted with the APEX telescope is the first survey covering the whole inner Galactic plane ($60^o > l > -60^o$ & $b < \pm 1.5^o$) in submm continuum emission tracing the cold dust of dense and young star-forming regions. Here, we present the overall distribution of sources within our Galactic disk. The submm continuum emission is confined to a narrow range around the galactic plane, but shifted on average by $\sim$0.07 deg

below the plane. Source number counts show strong enhancements toward the Galactic center, the spiral arms and toward prominent star-forming regions. Comparing the distribution of ATLASGAL dust continuum emission to that of young intermediate- to high-mass young stellar objects (YSOs) derived from Spitzer data, we find similarities as well as differences. In particular, the distribution of submm dust continuum emission is significantly more confined to the plane than the YSO distribution (FWHM of 0.7 and 1.1 deg, corresponding to mean physical scale heights of approximately 46 and 80 pc, respectively). While this difference may partly be caused by the large extinction from the dense submm cores, gradual dispersal of stellar distributions after their birth could also contribute to this effect. Compared to other tracers of Galactic structure, the ATLASGAL data are strongly confined to a narrow latitude strip around the Galactic plane.

Accepted by Astrophysical Journal

http://www.mpia-hd.mpg.de/homes/beuther/papers.html

The Hall effect in star formation

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Magnetic fields play an important role in star formation by regulating the removal of angular momentum from collapsing molecular cloud cores. Hall diffusion is known to be important to the magnetic field behaviour at many of the intermediate densities and field strengths encountered during the gravitational collapse of molecular cloud cores into protostars, and yet its role in the star formation process is not well-studied. We present a semianalytic self-similar model of the collapse of rotating isothermal molecular cloud cores with both Hall and ambipolar diffusion, and similarity solutions that demonstrate the profound influence of the Hall effect on the dynamics of collapse.

The solutions show that the size and sign of the Hall parameter can change the size of the protostellar disc by up to an order of magnitude and the protostellar accretion rate by fifty per cent when the ratio of the Hall to ambipolar diffusivities is varied between $-0.5 \leq \eta_H/\eta_A \leq 0.2$. These changes depend upon the orientation of the magnetic field with respect to the axis of rotation and create a preferred handedness to the solutions that could be observed in protostellar cores using next-generation instruments such as ALMA.

Hall diffusion also determines the strength and position of the shocks that bound the pseudo and rotationally-supported discs, and can introduce subshocks that further slow accretion onto the protostar. In cores that are not initially rotating (not examined here), Hall diffusion can even induce rotation, which could give rise to disc formation and resolve the magnetic braking catastrophe. The Hall effect clearly influences the dynamics of gravitational collapse and its role in controlling the magnetic braking and radial diffusion of the field merits further exploration in numerical simulations of star formation.

Accepted by MNRAS

http://arxiv.org/abs/1109.1370

The narrow, inner CO ring around the magnetic Herbig Ae star, HD 101412

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We describe and model emission lines in the first overtone band of CO in the magnetic Herbig Ae star HD 101412. High-resolution CRIRES spectra reveal unusually sharp features which suggest the emission is formed in a thin disk centered at 1 AU with a width 0.32 AU or less. A wider disk will not fit the observations. Previous observations have reached similar conclusions, but the crispness of the new material brings the emitting region into sharp focus.

Accepted by Astronomy and Astrophysics (Letters)

http://arxiv.org/abs/1112.6181

Protoplanetary Disks of T Tauri Binary Systems in the Orion Nebula Cluster

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Aims. We present a study of protoplanetary disks in spatially resolved low-mass binary stars in the well-known Orion Nebula Cluster (ONC) in order to assess the impact of binarity on the properties of circumstellar disks and its relation to the cluster environment. This is the currently largest such study in a clustered high stellar density star forming environment, as opposed to previous studies which have mostly focussed on the young, low stellar density, Taurus association. We particularly aim at determining the presence of magnetospheric accretion and dust disks for each binary component, and at measuring the overall disk frequency.
Methods. We carried out spatially resolved Adaptive Optics assisted near-infrared photometry and spectroscopy of 26 binaries in the ONC, and determine stellar parameters such as effective temperatures and spectral types, luminosities, masses, as well as accretion properties and near-infrared excess for individual binary components. Based on our medium resolution K-band spectroscopy we infer the presence of magnetospheric accretion around each binary component from measuring the strength of Brackett-γ emission. The best estimate of the observed accretion disk frequency among the ONC binaries is then derived from Bayesian statistics. The observed disk signatures, measured accretion luminosities and mass accretion rates are investigated with respect to binary separation, mass ratios, and distance to the center of the ONC.
Results. A fraction of $40^{+10}_{-9}\%$ of the binary components in the sample can be inferred to be T Tauri stars possesing an accretion disk. This is only marginally lower than the disk fraction of single stars of $\sim$50% in the ONC. We find that disks in wide binaries of >200 AU separation are consistent with random pairing, while the evolution of circumprimary and circumsecondary disks is observed to be synchronized in close binaries (separations <200AU). Circumbinary disks appear to be not suited to explain this difference. Further, we identify several mixed pairs of accreting and non-accreting components, suggesting that these systems are common, and without preference for the more or less massive component to evolve faster. The derived accretion luminosities and mass accretion rates of the ONC binary components are of similar magnitude as those for ONC single stars and for binaries in the Taurus star forming region. The paper concludes with a discussion of the (presumably weak) connection between the presence of inner accretion disks in young binary systems and the existence of planets in stellar multiples.

Accepted by Astronomy & Astrophysics

http://adsabs.harvard.edu/abs/2012arXiv1201.2421D

Production of interstellar hydrogen peroxide (H_2O_2) on the surface of dust grains

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Context. The formation of water on the dust grains in the interstellar medium may proceed with hydrogen peroxide (H_2O_2) as an intermediate. Recently gas-phase H_2O_2 has been detected in ρ Oph A with an abundance of $\sim10^{-10}$ relative to H_2.
Aims. We aim to reproduce the observed abundance of H_2O_2 and other species detected in ρ Oph A quantitatively.
Methods. We make use of a chemical network that includes gas phase reactions, as well as processes on the grains. Desorption from the grain surface through chemical reaction is also included. We ran the model for a range of physical parameters.
Results. The abundance of H_2O_2 can be best reproduced at $\sim6\times10^5$ yr, which is close to the dynamical age of ρ Oph A. The abundances of other species such as H_2CO, CH_3OH, and O_2 can also be reasonably reproduced at this time.

In the early time, the gas-phase abundance of H_2O_2 can be much higher than the currently detected value. We predict a gas phase abundance of O_2H at the same order of magnitude as H_2O_2, and an abundance on the order of 10^{-8} for gas phase water in ρ Oph A. A few other species of interest are also discussed.
Conclusions. We demonstrate that H_2O_2 can be produced on the dust grains and released into the gas phase through nonthermal desorption via surface exothermic reactions. The H_2O_2 molecule on the grain is an important intermediate in the formation of water. The fact that H_2O_2 is over-produced in the gas phase for a range of physical conditions suggests that its destruction channel in the current gas phase network may be incomplete.

Accepted by Astronomy and Astrophysics

http://arxiv.org/abs/1111.6477

37 GHz methanol masers : Horsemen of the Apocalypse for the class II methanol maser phase?

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We report the results of a search for class II methanol masers at 37.7, 38.3 and 38.5 GHz towards a sample of 70 high-mass star formation regions. We primarily searched towards regions known to show emission either from the 107 GHz class II methanol maser transition, or from the 6.035 GHz excited OH transition. We detected maser emission from 13 sources in the 37.7 GHz transition, eight of these being new detections. We detected maser emission from three sources in the 38 GHz transitions, one of which is a new detection. We find that 37.7 GHz methanol masers are only associated with the most luminous 6.7 and 12.2 GHz methanol maser sources, which in turn are hypothesised to be the oldest class II methanol sources. We suggest that the 37.7 GHz methanol masers are associated with a brief evolutionary phase (of 1000-4000 years) prior to the cessation of class II methanol maser activity in the associated high-mass star formation region.

Accepted by ApJ

preprint available at http://arxiv.org/abs/1110.3828

On the Transitional Disk Class: Linking Observations of T Tauri Stars & Physical Disk Models

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Two decades ago "transitional disks" described spectral energy distributions (SEDs) of T Tauri stars with small near-IR excesses, but significant mid- and far-IR excesses. Many inferred this indicated dust-free holes in disks, possibly cleared by planets. Recently, this term has been applied disparately to objects whose *Spitzer* SEDs diverge from the expectations for a typical full disk. Here we use irradiated accretion disk models to fit the SEDs of 15 such disks in NGC 2068 and IC 348. One group has a "dip" in infrared emission while the others' continuum emission decreases steadily at all wavelengths. We find that the former have an inner disk hole or gap at intermediate radii in the disk and we call these objects "transitional" and "pre-transitional" disks, respectively. For the latter group, we can fit these SEDs with full disk models and find that millimeter data are necessary to break the degeneracy between dust settling and disk mass. We suggest the term "transitional" only be applied to objects that display evidence for a radical change in the disk's radial structure. Using this definition, we find that transitional and pre-transitional disks tend to have lower mass accretion rates than full disks and that transitional disks have lower accretion rates than pre-transitional disks. These reduced accretion rates onto the star could be linked to forming planets. Future observations of transitional and pre-transitional disks will allow us to better quantify the signatures of planet formation in young disks.

Accepted by ApJ

http://arxiv.org/abs/1201.1518

Star formation and disk properties in Pismis 24

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Context. Circumstellar disks are expected to evolve quickly in massive young clusters harboring many OB-type stars. Two processes have been proposed to drive the disk evolution in such cruel environments: (1) gravitational interaction between circumstellar disks and nearby passing stars (stellar encounters), and (2) photoevaporation by UV photons from massive stars. The relative importance of both mechanisms is not well understood. Studies of massive young star clusters can provide observational constraints on the processes of driving disk evolution.
Aims. We investigate the properties of young stars and their disks in the NGC 6357 complex, concentrating on the most massive star cluster within the complex: Pismis 24.
Methods. We use infrared data from the 2MASS and Spitzer GLIMPSE surveys, complemented with our own deep Spitzer imaging of the central regions of Pismis 24, in combination with X-ray data to search for young stellar objects (YSOs) in NGC 6357 complex. The infrared data constrain the disk presence and are complemented by optical photometric and spectroscopic observations, obtained with VLT/VIMOS, that constrain the properties of the central stars. For those stars with reliable spectral types we combine spectra and photometry to estimate the mass and age. For cluster members without reliable spectral types we obtain the mass and age probability distributions from R and I-band photometry, assuming these stars have the same extinction distribution as those in the "spectroscopic" sample. We compare the disk properties in the Pismis 24 cluster with those in other clusters/star-forming regions employing infrared color-color diagrams.
Results. We discover two new young clusters in the NGC 6357 complex. We give a revised distance estimate for Pismis 24 of 1.7±0.2 kpc. We find that the massive star Pis 24-18 is a binary system, with the secondary being the main X-ray source of the pair. We provide photometry in 9 bands between 0.55 and 9 μm for the members of the Pismis 24 cluster. We derive the cluster mass function and find that up to the completeness limit at low masses it agrees well with the initial mass function of the Trapezium cluster. We derive a median age of 1 Myr for the Pismis 24 cluster members. We find five proplyds in HST archival imaging of the cluster, four of which are newly found. In all cases the proplyd tails are pointing directly away from the massive star system Pis 24-1. One proplyd shows a second tail, pointing away from Pis 24-2, suggesting this object is being photoevaporated from two directions simultaneously. We find that the global disk frequency (∼30%) in Pismis 24 is much lower than some other clusters of similar age, such as the Orion Nebula Cluster. When comparing the disk frequencies in 19 clusters/star-forming regions of various ages

and different (massive) star content, we find that the disks in clusters harboring extremely massive stars (typically earlier than O5), like Pismis 24, are dissipated roughly twice as quickly as in clusters/star-forming regions without extremely massive stars. Within Pismis 24, we find that the disk frequency within a projected distance of 0.6 pc from Pis 24-1 is substantially lower than at larger radii (∼19% vs. ∼37%). We argue for a combination of photoevaporation and irradiation with ionizing UV photons from nearby massive stars, causing increased MRI-induced turbulence and associated accretion activity, to play an important role in the dissipation of low-mass star disks in Pismis 24.

Accepted by A&A

http://arxiv.org/abs/1201.0833

Time-Series Photometry of Stars in and around the Lagoon Nebula. I. Rotation Periods of 290 Low-Mass Pre–Main-Sequence Stars in NGC 6530

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We have conducted a long-term, wide-field, high-cadence photometric monitoring survey of ∼50,000 stars in the Lagoon Nebula HII region. This first paper presents rotation periods for 290 low-mass stars in NGC 6530, the young cluster illuminating the nebula, and for which we assemble a catalog of infrared and spectroscopic disk indicators, estimated masses and ages, and X-ray luminosities. The distribution of rotation periods we measure is broadly uniform for $0.5 < P < 10$ d; the short-period cutoff corresponds to breakup. We observe no obvious bimodality in the period distribution, but we do find that stars with disk signatures rotate more slowly on average. The stars' X-ray luminosities are roughly flat with rotation period, at the saturation level ($\log L_X/L_{\rm bol} \approx -3.3$). However, we find a significant positive correlation between $L_X/L_{\rm bol}$ and co-rotation radius, suggesting that the observed X-ray luminosities are regulated by centrifugal stripping of the stellar coronae. The period–mass relationship in NGC 6530 is broadly similar to that of the Orion Nebula Cluster (ONC), but the slope of the relationship among the slowest rotators differs from that in the ONC and other young clusters. We show that the slope of the period–mass relationship for the slowest rotators can be used as a proxy for the age of a young cluster, and we argue that NGC 6530 may be slightly younger than the ONC, making it a particularly important touchstone for models of angular momentum evolution in young, low-mass stars.

Accepted by ApJ

Preprint: http://arxiv.org/abs/1112.2211

Brief video explaining key results: http://www.youtube.com/user/OSUAstronomy#p/u/1/WarGh6GiWu8

The G305 star-forming complex: a wide-area radio survey of ultra-compact HII regions

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We present wide-area radio continuum 5.5 and 8.8 GHz (5.5 and 3.4 cm) Australia Telescope Compact Array observations of the complex and rich massive star-forming region G305. The aim of this study is to perform an un-targeted survey of the region in search of the compact radio emission associated with ultra-compact (UC) HII regions. Observa-

tions presented here encompass the entire complex and have a maximum resolution of $\sim 1.5\times1.4$ *arcsec* and sensitivity of $\sim 0.07\,\mathrm{mJy\,beam^{-1}}$. By applying a data reduction method that emphasises small-scale structure, we are able to detect 71 compact radio sources distributed throughout the observed field. To explore the nature of these compact radio sources we compare to mid-infrared data and in this way identify 56 background sources, eight stellar radio sources, a single bright-rimmed cloud and six candidate UC HII regions. The physical properties of these candidate UC HII regions are determined and reveal five candidates have peak properties consistent with known UC HII regions with source radii ranging from 0.04–0.1 pc, emission measures from $2.56–10.3\times10^{-6}\,\mathrm{pc\,cm^{-6}}$ and electron densities of $0.34–1.03\times10^{4}\,\mathrm{cm^{-3}}$. We comment on these sites of recent massive star formation within G305 and by comparing to other star formation tracers (masers, NH, YSOs) build a picture of the star formation history of the region. Using these results we estimate a lower limit to the star formation rate for the region of $\sim 0.003\,\mathrm{M_{\odot}\,yr^{-1}}$.

Accepted by MNRAS

YSO jets in the Galactic Plane from UWISH2: I - MHO catalogue for Serpens and Aquila

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Jets and outflows from Young Stellar Objects (YSOs) are important signposts of currently ongoing star formation. In order to study these objects we are conducting an unbiased survey along the Galactic Plane in the 1-0 S(1) emission line of molecular hydrogen at $2.122\,\mu$m using the UK Infrared Telescope. In this paper we are focusing on a 33 square degree sized region in Serpens and Aquila ($18°<l<30°$; $-1.5°<b<+1.5°$).
We trace 131 jets and outflows from YSOs, which results in a 15 fold increase in the total number of known Molecular Hydrogen Outflows. Compared to this, the total integrated 1-0 S(1) flux of all objects just about doubles, since the known objects occupy the bright end of the flux distribution. Our completeness limit is $3\cdot10^{-18}\,\mathrm{W\,m^{-2}}$ with 70 % of the objects having fluxes of less than $10^{-17}\,\mathrm{W\,m^{-2}}$.
Generally, the flows are associated with Giant Molecular Cloud complexes and have a scale height of $25-30$ pc with respect to the Galactic Plane. We are able to assign potential source candidates to about half the objects. Typically, the flows are clustered in groups of $3-5$ objects, within a radius of 5 pc. These groups are separated on average by about half a degree, and 2/3rd of the entire survey area is devoid of outflows. We find a large range of apparent outflow lengths from 4 arcsec to 130 arcsec. If we assume a distance of 3 kpc, only 10 % of all outflows are of parsec scale. There is a $2.6\,\sigma$ over abundance of flow position angles roughly perpendicular to the Galactic Plane.

Accepted by MNRAS

http://astro.kent.ac.uk/uwish2/papers/serpens1.pdf

On the nature of the transitional disk around LkCa15

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We present CARMA 1.3 mm continuum observations of the T Tauri star LkCa 15, which resolve the circumstellar dust continuum emission on angular scales between 0.2 arcsec-3 arcsec, corresponding to 28-420 AU at the distance of the star. The observations resolve the inner gap in the dust emission and reveal an asymmetric dust distribution in the outer disk. By comparing the observations with theoretical disk models, we calculate that 90% of the dust emission arises from an azimuthally symmetric ring that contains about 5×10^{-4} $\mathrm{M_{\odot}}$ of dust. A low surface-brightness tail that extends to the northwest out to a radius of about 300 AU contains the remaining 10% of the observed continuum emission. The ring is modeled with a rather flat surface density profile between 40 and 120 AU, while the inner cavity is consistent with either a sharp drop of the 1.3 mm dust optical depth at about 42 AU or a smooth inward decrease between 3 and 85 AU. We show that early science ALMA observations will be able to disentangle these two scenarios. Within 40 AU, the observations constrain the amount of dust between 10^{-6} and 7 Earth masses, where the minimum and maximum limits are set by the near-infrared SED modeling and by the millimeter-wave observations of

the dust emission respectively. In addition, we confirm the discrepancy in the outer disk radius inferred from the dust and gas, which corresponds to 150 AU and 900 AU respectively. We cannot reconcile this difference by adopting an exponentially tapered surface density profile as suggested for other systems, but we instead suggest that the gas surface density in the outer disk decreases less steeply than that predicted by model fits to the dust continuum emission. The lack of continuum emission at radii lager than 120 AU suggests a drop of at least a factor of 5 in the dust-to-gas ratio, or in the dust opacity. We show that a sharp dust opacity drop of this magnitude is consistent with a radial variation of the grain size distribution as predicted by existing grain growth models.

Accepted by The Astrophysical Journal

http://www.astro.caltech.edu/ isella/preprints/

AzTEC 1.1 mm Observations of the MBM12 Molecular Cloud

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We present 1.1 mm observations of the dust continuum emission from the MBM12 high-latitude molecular cloud observed with the Astronomical Thermal Emission Camera (AzTEC) mounted on the James Clerk Maxwell Telescope on Mauna Kea, Hawaii. We surveyed a 6.34 deg^2 centered on MBM12, making this the largest area that has ever been surveyed in this region with submillimeter and millimeter telescopes. Eight secure individual sources were detected with a signal-to-noise ratio of over 4.4. These eight AzTEC sources can be considered to be real astronomical objects compared to the other candidates based on calculations of the false detection rate. The distribution of the detected 1.1 mm sources or compact 1.1 mm peaks is spatially anti-correlated with that of the 100 μm emission and the ^{12}CO emission. We detected the 1.1 mm dust continuum emitting sources associated with two classical T Tauri stars, LkHα262 and LkHα264. Observations of spectral energy distributions (SEDs) indicate that LkHα262 is likely to be Class II (pre-main-sequence star), but there are also indications that it could be a late Class I (protostar). A flared disk and a bipolar cavity in the models of Class I sources lead to more complicated SEDs. From the present AzTEC observations of the MBM12 region, it appears that other sources detected with AzTEC are likely to be extragalactic and located behind MBM12. Some of these have radio counterparts and their star formation rates are derived from a fit of the SEDs to the photometric evolution of galaxies in which the effects of a dusty interstellar medium have been included.

Accepted by The Astrophysical Journal

Testing the universality of star formation - I. Multiplicity in nearby star-forming regions

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We have collated multiplicity data for five clusters (Taurus, Chamaeleon I, Ophiuchus, IC348, and the Orion Nebula Cluster). We have applied the same mass ratio (flux ratios of $\Delta K \leq 2.5$) and primary mass cuts ($\sim$0.1–3.0 M$_\odot$) to each cluster and therefore have directly comparable binary statistics for all five clusters in the separation range 62–620 au,

and for Taurus, Chamaeleon I, and Ophiuchus in the range 18–830 au. We find that the trend of decreasing binary fraction with cluster density is solely due to the high binary fraction of Taurus, the other clusters show no obvious trend over a factor of nearly 20 in density. With N-body simulations we attempt to find a set of initial conditions that are able to reproduce the density, morphology and binary fractions of all five clusters. Only an initially clumpy (fractal) distribution with an initial total binary fraction of 73 per cent (17 per cent in the range 62–620 au) is able to reproduce all of the observations (albeit not very satisfactorily). Therefore, if star formation is universal the initial conditions must be clumpy and with a high (but not 100 per cent) binary fraction. This could suggest that most stars, including M-dwarfs, form in binaries.

Accepted by MNRAS

http://xxx.lanl.gov/abs/1201.1311

Simulating protostellar evolution and radiative feedback in the cluster environment

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Radiative feedback is among the most important consequences of clustered star formation inside molecular clouds. At the onset of star formation, radiation from massive stars heats the surrounding gas, which suppresses the formation of many low-mass stars. When simulating pre-main-sequence stars, their stellar properties must be defined by a prestellar model. Different approaches to prestellar modeling may yield quantitatively different results. In this paper, we compare two existing prestellar models under identical initial conditions to gauge whether the choice of model has any significant effects on the final population of stars. The first model treats stellar radii and luminosities with a ZAMS model, while separately estimating the accretion luminosity by interpolating to published prestellar tracks. The second, more accurate prestellar model self-consistently evolves the radius and luminosity of each star under highly variable accretion conditions. Each is coupled to a raytracing-based radiative feedback code that also treats ionization. The impact of the self-consistent model is less ionizing radiation and less heating during the early stages of star formation. This may affect final mass distributions. We noted a peak stellar mass reduced by 8% from 47.3 Msun to 43.5 Msun in the evolutionary model, relative to the track-fit model. Also, the difference in mass between the two largest stars in each case is reduced from 14 Msun to 7.5 Msun. The HII regions produced by these massive stars were also seen to flicker on timescales down to the limit imposed by our timestep (¡ 560 years), rapidly changing in size and shape, confirming previous cluster simulations using ZAMS-based estimates for prestellar ionizing flux.

Accepted by MNRAS

http://arxiv.org/abs/1112.4070

Magnetic Field Strength Maps for Molecular Clouds: A New Method Based on a Polarization - Intensity Gradient Relation

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Dust polarization orientations in molecular clouds often tend to be close to tangential to the Stokes I dust continuum emission contours. The magnetic field and the emission gradient orientations, therefore, show some correlation. A method is proposed, which – in the framework of ideal magneto-hydrodynamics (MHD) – connects the measured angle between magnetic field and emission gradient orientations to the total field strength. The approach is based on the assumption that a change in emission intensity (gradient) is a measure for the resulting direction of motion in the MHD force equation. In particular, this new method leads to maps of position-dependent magnetic field strength estimates. When evaluating the field curvature and the gravity direction locally on a map, the method can be generalized to arbitrary cloud shapes. The technique is applied to high-resolution ($\sim$0.7 arcsec) Submillimeter Array polarization data of the collapsing core W51 e2. A tentative $\sim$ 7.7 mG field strength is found when averaging over the entire core. The analysis further reveals some structures and an azimuthally averaged radial profile $\sim r^{-1/2}$ for the field strength. Maximum values close to the center are around 19 mG. The currently available observations lack higher resolution data to probe the innermost part of the core where the largest field strength is expected from the method. Application regime and limitations of the method are discussed. As a further important outcome of this technique, the local significance of the magnetic field force compared to the other forces can be quantified in a model-independent way, from measured angles only. Finally, the method can potentially also be expanded and applied to other objects (besides molecular clouds) with measurements that reveal the field morphology, as e.g. Faraday rotation measurements in galaxies.

Accepted by ApJ

Quantifying the Significance of the Magnetic Field from Large-Scale Cloud to Collapsing Core: Self-Similarity, Mass-to-Flux Ratio and Star Formation Efficiency

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Dust polarization observational results are analyzed for the high-mass star formation region W51 from the largest parent cloud ($\sim$ 2 pc, JCMT) to the large-scale envelope ($\sim$ 0.5 pc, BIMA) down to the collapsing core e2 ($\sim$ 60 mpc, SMA). Magnetic field and dust emission gradient orientations reveal a correlation which becomes increasingly more tight with higher resolution. The previously developed polarization - intensity gradient method (Koch et al. 2012) is applied in order to quantify the magnetic field significance. This technique provides a way to estimate the local magnetic field force compared to gravity without the need of any mass or field strength measurements, solely making use of measured angles which reflect the geometrical imprint of the various forces. All three data sets clearly show regions with distinct features in the field-to-gravity force ratio. Azimuthally averaged radial profiles of this force ratio reveal a transition from a field dominance at larger distances to a gravity dominance closer to the emission peaks. Normalizing these profiles to a characteristic core scale points toward self-similarity. Furthermore, the polarization intensity-gradient method is linked to the mass-to-flux ratio, providing a new approach to estimate the latter one without mass and field strength inputs. A transition from a magnetically supercritical to a subcritical state as a function of distance from the emission peak is found for the e2 core. Finally, based on the measured radius-dependent field-to-gravity force ratio we derive a modified star formation efficiency with a diluted gravity force. Compared to a standard (free-fall) efficiency, the observed field is capable of reducing the efficiency down to 10% or less.

Accepted by ApJ

http://arxiv.org/pdf/1201.4313.pdf

Massive star-formation toward G28.87+0.07 (IRAS 18411-0338) investigated by means of maser kinematics and radio to infrared, continuum observations

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We used the Very Long Baseline Array (VLBA) and the European VLBI Network (EVN) to perform phase-referenced VLBI observations of the three most powerful maser transitions associated with the high-mass star-forming region G28.87+0.07: the 22.2 GHz H_2O, 6.7 GHz CH_3OH, and 1.665 GHz OH lines. We also performed VLA observations of the radio continuum emission at 1.3 and 3.6 cm and Subaru observations of the continuum emission at 24.5 μm. Two centimeter continuum sources are detected and one of them (named "HMC") is compact and placed at the center of the observed distribution of H_2O, CH_3OH and OH masers. The bipolar distribution of line-of-sight (l.o.s) velocities and the pattern of the proper motions suggest that the water masers are driven by a (proto)stellar jet interacting with the dense circumstellar gas. The same jet could both excite the centimeter continuum source named "HMC" (interpreted as free-free emission from shocked gas) and power the molecular outflow observed at larger scales – although one cannot exclude that the free-free continuum is rather originating from a hypercompact HII region. At 24.5 μm, we identify two objects separated along the north-south direction, whose absolute positions agree with those of the two VLA continuum sources. We establish that ∼90% of the luminosity of the region ($\sim 2\times10^5$ $L_\odot$) is coming from the radio source "HMC", which confirms the existence of an embedded massive young stellar object (MYSO) exciting the masers and possibly still undergoing heavy accretion from the surrounding envelope.

Accepted by The Astrophysical Journal

Is FS Tau B Driving an Asymmetric Jet?

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FS Tau B is one of the few T Tauri stars that possess a jet and a counterjet as well as an optically-visible cavity wall. We obtained images and spectra of its jet-cavity system in the near-infrared H and K bands using Subaru/IRCS and detected the jet and the counterjet in the [Fe II] 1.644 μm line for the first time. Within the inner $2''$ the blueshifted jet is brighter, whereas beyond $\sim 5''$ the redshifted counterjet dominates the [Fe II] emission. The innermost blueshifted knot is spectrally resolved to have a large line width of ~ 110 km s^{-1}, while the innermost redshifted knot appears spectrally unresolved. The velocity ratio of the jet to the counterjet is ~ 1.34, which suggests that FS Tau B is driving an asymmetric jet, similar to those found in several T Tauri Stars. Combining with optical observations in the literature, we showed that the blueshifted jet has lower density and higher excitation than the redshifted counterjet. We suggest that the asymmetry in brightness and velocity is the manifestation of a bipolar outflow driving at different mass-loss rates, while maintaining balance of linear momentum. A full explanation to the asymmetry in the FS Tau B system awaits detail modeling and further investigation of the kinematic structure of the wind-associated cavity walls.

Accepted by Astrophysical Journal

http://arxiv.org/abs/1201.1487

Spin Evolution of Accreting Young Stars. II. Effect of Accretion-Powered Stellar Winds

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We present a model for the rotational evolution of a young, solar-mass star interacting magnetically with an accretion disk. As in a previous paper (Paper I), the model includes changes in the star's mass and radius as it descends the Hayashi track, a decreasing accretion rate, and a prescription for the angular momentum transfer between the star and disk. Paper I concluded that, for the relatively strong magnetic coupling expected in real systems, additional processes are necessary to explain the existence of slowly rotating pre-main-sequence stars. In the present paper, we extend the stellar spin model to include the effect of a spin-down torque that arises from an accretion-powered stellar wind. For a range of magnetic field strengths, accretion rates, initial spin rates, and mass outflow rates, the modeled stars exhibit rotation periods within the range of 1–10 days in the age range of 1–3 Myr. This range coincides with the bulk of the observed rotation periods, with the slow rotators corresponding to stars with the lowest accretion rates, strongest magnetic fields, and/or highest stellar wind mass outflow rates. We also make a direct, quantitative comparison between the accretion-powered stellar wind scenario and the two types of disk-locking models (namely the X-wind and Ghosh & Lamb type models) and identify some remaining theoretical issues for understanding young star spins.

Accepted by ApJ

http://adsabs.harvard.edu/abs/2012ApJ...745..101M

A (sub)millimetre study of dense cores in Orion B9

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Context: Studies of dense molecular-cloud cores at (sub)millimetre wavelengths are needed to understand the early stages of star formation.
Aims: We aim to further constrain the properties and evolutionary stages of dense cores in Orion B9. The prime objective of this study is to examine the dust emission of the cores near the peak of their spectral energy distributions, and to determine the degrees of CO depletion, deuterium fractionation, and ionisation.
Methods: The central part of Orion B9 was mapped at 350 μm with APEX/SABOCA. A sample of nine cores in the region were observed in $C^{17}O(2-1)$, $H^{13}CO^+(4-3)$ (towards 3 sources), $DCO^+(4-3)$, $N_2H^+(3-2)$, and $N_2D^+(3-2)$ with APEX/SHFI. These data are used in conjunction with our previous APEX/LABOCA 870-μm dust continuum data.
Results: All the LABOCA cores in the region covered by our SABOCA map were detected at 350 μm. The strongest 350 μm emission is seen towards the Class 0 candidate SMM 3. Many of the LABOCA cores show evidence of substructure in the higher-resolution SABOCA image. In particular, we report on the discovery of multiple very low-mass condensations in the prestellar core SMM 6. Based on the 350-to-870 μm flux density ratios, we determine dust temperatures of $T_{\rm dust} \simeq 7.9 - 10.8$ K, and dust emissivity indices of $\beta \sim 0.5 - 1.8$. The CO depletion factors are in the range $f_{\rm D} \sim 1.6 - 10.8$. The degree of deuteration in N_2H^+ is $\simeq 0.04 - 0.99$, where the highest value (seen towards the prestellar core SMM 1) is, to our knowledge, the most extreme level of N_2H^+ deuteration reported so far. The level of HCO^+ deuteration is about 1–2%. The fractional ionisation and cosmic-ray ionisation rate of H_2 could be determined only towards two sources with the lower limits of $\sim 2 - 6 \times 10^{-8}$ and $\sim 2.6 \times 10^{-17} - 4.8 \times 10^{-16}$ s^{-1}, respectively. We also detected D_2CO towards two sources.
Conclusions: The detected protostellar cores are classified as Class 0 objects, in agreement with our previous SED results. The detection of subcondensations within SMM 6 shows that core fragmentation can already take place during the prestellar phase. The origin of this substructure is likely caused by thermal Jeans fragmentation of the elongated parent core. Varying levels of $f_{\rm D}$ and deuteration among the cores suggest that they are evolving chemically at different rates. A low $f_{\rm D}$ value and the presence of gas-phase D_2CO in SMM 1 suggest that the core chemistry is affected by the nearby outflow. The very high N_2H^+ deuteration in SMM 1 is likely to be remnant of the earlier CO-depleted phase.

Accepted by Astronomy and Astrophysics

http://arxiv.org/abs/1112.5053

Probing the turbulent mixing strength in protoplanetary disks across the stellar mass range: no significant variations

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Dust settling and grain growth are the first steps in the planet-formation process in protoplanetary disks. These disks are observed around stars with different spectral types, and there are indications that the disks around lower mass stars are significantly flatter, which could indicate that they settle and evolve faster, or in a different way.
We aim to test this hypothesis by modeling the median spectral energy distributions (SEDs) of three samples of protoplanetary disks: around Herbig stars, T Tauri stars and brown dwarfs. We focus on the turbulent mixing strength to avoid a strong observational bias from disk and stellar properties that depend on stellar mass.
We generated SEDs with the radiative transfer code MCMax, using a hydrostatic disk structure and settling the dust in a self-consistent way with the α-prescription to probe the turbulent mixing strength.
We are able to fit all three samples with a disk with the same input parameters, scaling the inner edge to the dust evaporation radius and disk mass to millimeter photometry. The Herbig stars require a special treatment for the inner rim regions, while the T-Tauri stars require viscous heating, and the brown dwarfs lack a good estimate of the disk mass because only few millimeter detections exist.
We find that the turbulent mixing strength does not vary across the stellar mass range for a fixed grain size distribution and gas-to-dust ratio. Regions with the same temperature have a self-similar vertical structure independent of stellar mass, but regions at the same distance from the central star appear more settled in disks around lower mass stars. We find a relatively low turbulent mixing strength of $\alpha = 10^{-4}$ for a standard grain size distribution, but our results are also consistent with $\alpha = 10^{-2}$ for a grain size distribution with fewer small grains or a lower gas-to-dust ratio.

Accepted by A&A

http://arxiv.org/abs/1201.1453

Mid-infrared variability of the binary system CS Cha

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CS Cha is a binary system surrounded by a circumbinary disk. We construct a model for the inner disk regions and compare the resulting synthetic spectral energy distribution (SED) with Infrared Spectrograph spectra of CS Cha taken at two different epochs. For our model we adopt a non-axisymmetric mass distribution from results of published numerical simulations of the interaction between a circumbinary disk and a binary system, where each star is surrounded by a disk. In particular, we approximate the streams of mass from which the inner circumstellar disks accrete from the circumbinary disk. This structure is due to the gravitational interaction of the stars with the disk, in which an array of disks and streams is formed in an inner hole. We calculate the temperature distribution of the optically thin dust in these inner regions considering the variable impinging radiation from both stars and use the observations to estimate the mass variations in the streams. We find that the SEDs for both epochs can be explained with emission from an optically thick inner edge of the circumbinary disk and from the optically thin streams that connect the circumbinary disk with the two smaller circumstellar disks. To the best of our knowledge, this is the first time that the emission from the optically thin material in the hole, suggested by the theory, is tested against

observations of a binary system.

Accepted by Astrophysical Journal

Wide-Field Survey of Emission-line Stars in IC1396

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We have made an extensive survey of emission-line stars in the IC 1396 H II region to investigate the low-mass population of pre-main sequence (PMS) stars. A total of 639 Hα emission-line stars were detected in an area of 4.2 deg^2 and their i'-photometry was measured. Their spatial distribution exhibits several aggregates near the elephant trunk globule (Rim A) and bright-rimmed clouds at the edge of the H II region (Rim B and SFO 37, 38, 39, 41), and near HD 206267, which is the main exciting star of the H II region. Based on the extinction estimated from the near-infrared (NIR) color–color diagram, we have selected pre-main sequence star candidates associated with IC 1396. The age and mass were derived from the extinction corrected color-magnitude diagram and theoretical pre-main sequence tracks. Most of our PMS candidates have ages of < 3 Myr and masses of 0.2–0.6 $M_\odot$. Although it appears that only a few stars were formed in the last 1 Myr in the east region of the exciting star, the age difference among subregions in our surveyed area is not clear from the statistical test. Our results may suggest that massive stars were born after the continuous formation of low-mass stars for 10 Myr. The birth of the exciting star could be the late stage of slow but contiguous star formation in the natal molecular cloud. It may have triggered to form many low-mass stars at the dense inhomogeneity in and around the H II region by a radiation-driven implosion.

Accepted by Astronomical Journal

http://arxiv.org/abs/1201.2761

Thermal desorption characteristics of CO, O_2 and CO_2 on non-porous water, crystalline water and silicate surfaces at sub-monolayer and multilayer coverages.

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The desorption characteristics of molecules on interstellar dust grains are important for modelling the behaviour of molecules in icy mantles and, critically, in describing the solid-gas interface. In this study, a series of laboratory experiments exploring the desorption of three small molecules from three astrophysically relevant surfaces is presented. The desorption of CO, O_2 and CO_2 at both sub-monolayer and multilayer coverages was investigated from non-porous water, crystalline water and silicate surfaces. Experimental data was modelled using the Polanyi-Wigner equation to produce a mathematical description of the desorption of each molecular species from each type of surface, uniquely describing both the monolayer and multilayer desorption in a single combined model. The implications of desorption behaviour over astrophysically relevant timescales are discussed.

Accepted by MNRAS

http://arxiv.org/abs/1112.2162

Numerical convergence in self-gravitating shearing sheet simulations and the stochastic nature of disc fragmentation

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We study numerical convergence in local two-dimensional hydrodynamical simulations of self-gravitating accretion discs with a simple cooling law. It is well-known that there exists a steady gravito-turbulent state, in which cooling is balanced by dissipation of weak shocks, with a net outward transport of angular momentum. Previous results indicated that if cooling is too fast (typical time scale 3 Ω^{-1}, where Ω is the local angular velocity), this steady state can not be maintained and the disc will fragment into gravitationally bound clumps. We show that, in the two-dimensional local approximation, this result is in fact not converged with respect to numerical resolution and longer time integration. Irrespective of the cooling time scale, gravito-turbulence consists of density waves as well as transient clumps. These clumps will contract because of the imposed cooling, and collapse into bound objects if they can survive for long enough. Since heating by shocks is very local, the destruction of clumps is a stochastic process. High numerical resolution and long integration times are needed to capture this behaviour. We have observed fragmentation for cooling times up to 20 Ω^{-1}, almost a factor 7 higher than in previous simulations. Fully three-dimensional simulations with a more realistic cooling prescription are necessary to determine the effects of the use of the two-dimensional approximation and a simple cooling law.

Accepted by MNRAS

A Revised Age for Upper Scorpius and The Star-Formation History Among the F-Type Members of the Scorpius-Centaurus OB Association

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We present an analysis of the ages and star-formation history of the F-type stars in the Upper Scorpius (US), Upper Centaurus-Lupus (UCL) and Lower Centaurus-Crux (LCC) subgroups of Scorpius-Centaurus (Sco-Cen), the nearest OB association. Our parent sample is the kinematically-selected *Hipparcos* sample of de Zeeuw et al., restricted to the 138 F-type members. We have obtained classification-resolution optical spectra and have also determined the spectroscopic accretion disk fraction. With *Hipparcos* and 2MASS photometry, we estimate the reddening and extinction for each star and place the candidate members on a theoretical H-R diagram. For each subgroup we construct empirical isochrones and compare to published evolutionary tracks. We find that (1) our empirical isochrones are consistent with the previously published age-rank of the Sco-Cen subgroups, (2) subgroups LCC and UCL appear to reach the main sequence turn-on at spectral types ~F4 and ~F2, respectively. An analysis of the A-type stars shows US reaching the main sequence at about spectral type ~A3. (3) The median ages for the pre-main sequence members of UCL and LCC are 16 Myr and 17 Myr, respectively, in agreement with previous studies, however we find that (4) Upper Sco is much older than previously thought. The luminosities of the F-type stars in US are typically a factor of ~2.5 less luminous than predicted for a 5 Myr old population for four sets of evolutionary tracks. We re-examine the evolutionary state and isochronal ages for the B-, A-, and G-type Upper Sco members, as well as the evolved M supergiant Antares, and estimate a revised mean age for Upper Sco of 11±1±2 Myr (statistical, systematic). Using radial velocities and *Hipparcos* parallaxes we calculate a lower limit on the kinematic expansion age for Upper Sco of >10.5 Myr (99% confidence). However, the data are statistically consistent with no expansion. We reevaluate the inferred masses for the known substellar companions in Upper Sco using the revised age and find that the inferred masses are typically ~20–70% higher than the original estimates which had assumed a much younger age; specifically, we estimate the mass of 1RXS J1609-2105b to be 14^{+2}_{-3} M_{Jup}, suggesting that it is a brown dwarf rather than a planet. Finally, we find the fraction of F-type stars exhibiting Hα emission and/or a K-band excess consistent with accretion to be 0/17 ($<$ 19%; 95% C.L.) in US at ~11 Myr, while UCL has 1/41 (2^{+5}_{-1}%; 68% C.L.) accretors and LCC has 1/50 (2^{+4}_{-1}%; 68% C.L.) accretors at ~16 Myr and ~17 Myr, respectively.

Accepted by Astrophysical Journal

http://arxiv.org/abs/1112.1695

Modes of Star Formation in Finite Molecular Clouds

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We analytically investigate the modes of gravity-induced star formation possible in idealized finite molecular clouds where global collapse competes against both local Jeans instabilities and discontinuous edge instabilities. We examine these timescales for collapse in spheres, discs, and cylinders, with emphasis on the structure, size, and degree of internal perturbations required in order for local collapse to occur before global collapse. We find that internal, local collapse is more effective for the lower dimensional objects. Spheres and discs, if unsupported against global collapse, must either contain strong perturbations or must be unrealistically large in order for small density perturbations to collapse significantly faster than the entire cloud. We find, on the other hand, that filamentary geometry is the most favorable situation for the smallest perturbations to grow before global collapse overwhelms them and that filaments containing only a few Jeans masses and weak density perturbations can readily fragment. These idealized solutions are compared with simulations of star-forming regions in an attempt to delineate the role of global, local, and edge instabilities in determining the fragmentation properties of molecular clouds. The combined results are also discussed in the context of recent observations of Galactic molecular clouds.

Accepted by ApJ

http://arxiv.org/abs/1108.1395

Molecular Tracers of Turbulent Shocks in Giant Molecular Clouds

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Giant molecular clouds contain supersonic turbulence and simulations of MHD turbulence show that these supersonic motions decay in roughly a crossing time, which is less than the estimated lifetimes of molecular clouds. Such a situation requires a significant release of energy. We run models of C-type shocks propagating into gas with densities around 10^3 cm^{-3} at velocities of a few km s^{-1}, appropriate for the ambient conditions inside of a molecular cloud, to determine which species and transitions dominate the cooling and radiative energy release associated with shock cooling of turbulent molecular clouds. We find that these shocks dissipate their energy primarily through CO rotational transitions and by compressing pre-existing magnetic fields. We present model spectra for these shocks and by combining these models with estimates for the rate of turbulent energy dissipation, we show that shock emission should dominate over emission from unshocked gas for mid to high rotational transitions ($J > 5$) of CO. We also find that the turbulent energy dissipation rate is roughly equivalent to the cosmic ray heating rate and that the ambipolar diffusion heating rate may be significant, especially in shocked gas.

Accepted by ApJ

http://arxiv.org/abs/1201.1919

Very Large Array Observations of Ammonia in Infrared-Dark Clouds II: Internal Kinematics

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Infrared-dark clouds (IRDCs) are believed to be the birthplaces of rich clusters and thus contain the earliest phases of high-mass star formation. We use the Green Bank Telescope (GBT) and Very Large Array (VLA) maps of ammonia (NH_3) in six IRDCs to measure their column density and temperature structure (Paper 1), and here, we investigate the kinematic structure and energy content. We find that IRDCs overall display organized velocity fields, with only localized disruptions due to embedded star formation. The local effects seen in NH_3 emission are not high velocity outflows but rather moderate (few km s^{-1}) increases in the line width that exhibit maxima near or coincident with the mid-infrared emission tracing protostars. These line width enhancements could be the result of infall or (hidden in NH_3 emission) outflow. Not only is the kinetic energy content insufficient to support the IRDCs against collapse, but also the spatial energy distribution is inconsistent with a scenario of turbulent cloud support. We conclude that the velocity signatures of the IRDCs in our sample are due to active collapse and fragmentation, in some cases augmented by local feedback from stars.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1201.1402v1

V900 Mon and Thommes' Nebula: A New FUor in Monoceros

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Detailed observations of a recently recognized eruptive variable, V900 Mon, are presented. The star is located in the small cloud L1656, a little-studied region of modest star formation activity in Monoceros, and is presently at a magnitude of $r{\sim}16$, surrounded by a bright compact reflection nebula, where only a 20th magnitude star was seen on the red first-epoch POSS plate. Optical spectra show a red absorption-line spectrum not later than mid-K, and the Hα line and the Na I D_{12} doublet display prominent P Cygni profiles with massive absorption troughs indicating a cool outflowing wind. Near-infrared spectra show deep CO bandhead absorption and pronounced molecular bands of water vapor indicative of a much cooler object. This spectral appearance is very similar to that of FU Orionis, except that V900 Mon has a much higher reddening of $A_V{\sim}13$ magnitudes. The energy distribution of V900 Mon, compiled from non-simultaneous observations and thus dependent on possible luminosity changes, shows that V900 Mon is a Class I protostar with a massive cool envelope. At a distance of about 1100 pc, V900 Mon has a luminosity of 106 $L_\odot$ in the range 0.55 μm to 160 μm. These data identify V900 Mon as a new member of the rare class of FU Orionis variables.

Accepted by ApJ Letters

http://www.ifa.hawaii.edu/users/reipurth/PREPRINTS/ms_V900Mon.pdf

What Sets the Initial Rotation Rates of Massive Stars?

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The physical mechanisms that set the initial rotation rates in massive stars are a crucial unknown in current star formation theory. Observations of young, massive stars provide evidence that they form in a similar fashion to their low-mass counterparts. The magnetic coupling between a star and its accretion disk may be sufficient to spin down low-mass pre-main sequence (PMS) stars to well below breakup at the end stage of their formation when the accretion rate is low. However, we show that these magnetic torques are insufficient to spin down massive PMS stars due to their short formation times and high accretion rates. We develop a model for the angular momentum evolution of stars over a wide range in mass, considering both magnetic and gravitational torques. We find that magnetic torques are unable to spin down either low or high mass stars during the main accretion phase, and that massive stars cannot be spun down significantly by magnetic torques during the end stage of their formation either. Spin-down occurs only if massive stars' disk lifetimes are substantially longer or their magnetic fields are much stronger than current observations suggest.

Accepted by The Astrophysical Journal

http://ucolick.org/∼rosen/ucolick_rosen/Publications_files/alr_final_arxiv.pdf

Herschel Observations of a Potential Core Forming Clump: Perseus B1-E

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We present continuum observations of the Perseus B1-E region from the Herschel Gould Belt Survey. These Herschel data reveal a loose grouping of substructures at 160 - 500 micron not seen in previous submillimetre observations. We measure temperature and column density from these data and select the nine densest and coolest substructures for follow-up spectral line observations with the Green Bank Telescope. We find that the B1-E clump has a mass of ~ 100 solar masses and appears to be gravitationally bound. Furthermore, of the nine substructures examined here, one substructure (B1-E2) appears to be itself bound. The substructures are typically less than a Jeans length from their nearest neighbour and thus, may interact on a timescale of ~ 1 Myr. We propose that B1-E may be forming a first generation of dense cores, which could provide important constraints on the initial conditions of prestellar core formation. Our results suggest that B1-E may be influenced by a strong, localized magnetic field, but further observations are still required.

Accepted by Astronomy and Astrophysics

http://arxiv.org/abs/1111.7021

The Role of Turbulent Magnetic Reconnection on the Formation of Rotationally Supported Protostellar Disks

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The formation of protostellar disks out of molecular cloud cores is still not fully understood. Under ideal MHD conditions, the removal of angular momentum from the disk progenitor by the typically embedded magnetic field may prevent the formation of a rotationally supported disk during the main protostellar accretion phase of low-mass stars. This has been known as the magnetic braking problem and the most investigated mechanism to alleviate this problem and help remove the excess of magnetic flux during the star formation process, the so-called ambipolar diffusion (AD), has been shown to be not sufficient to weaken the magnetic braking at least at this stage of the disk formation. In this work, motivated by recent progress in the understanding of magnetic reconnection in turbulent environments, we appeal to the diffusion of magnetic field mediated by magnetic reconnection as an alternative mechanism for removing magnetic flux. We investigate numerically this mechanism during the later phases of the protostellar disk formation and show its high efficiency. By means of fully three-dimensional MHD simulations, we show that the diffusivity arising from turbulent magnetic reconnection is able to transport magnetic flux to the outskirts of the disk progenitor at timescales compatible with the collapse, allowing the formation of a rotationally supported disk around the protostar of dimensions B100 AU, with a nearly Keplerian profile in the early accretion phase. Since MHD turbulence is expected to be present in protostellar disks, this is a natural mechanism for removing magnetic flux excess and allowing the formation of these disks. This mechanism dismisses the necessity of postulating a hypothetical increase of the ohmic resistivity as discussed in the literature. Together with our earlier work which showed that magnetic flux removal from molecular cloud cores is very efficient, this work calls for reconsidering the relative role of AD for the processes of star and planet formations.

Accepted by The Astrophysical Journal

Dark Matter as an active gravitational agent in cloud complexes

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We study the effect that the dark matter background (DMB) has on the gravitational energy content and, in general, on the star formation efficiency of a molecular cloud (MC). We first analyze the effect that a dark matter halo, described by the Navarro et al. (1996) density profile, has on the energy budget of a spherical, homogeneous, cloud located at different distances from the halo center. We found that MCs located in the innermost regions of a massive galaxy can feel a contraction force greater than their self-gravity due to the incorporation of the potential of the galaxy's dark matter halo. We also calculated analytically the gravitational perturbation that a MC produces over a uniform DMB (uniform at the scales of a MC) and how this perturbation will affect the evolution of the MC itself. The study shows that the star formation in a MC will be considerably enhanced if the cloud is located in a dense and low velocity dark matter environment. We confirm our results by measuring the star formation efficiency in numerical simulations of the formation and evolution of MCs within different DMBs. Our study indicates that there are situations where the dark matter's gravitational contribution to the evolution of the molecular clouds should not be neglected.

Accepted by Astrophysical Journal

Search for starless clumps in the ATLASGAL survey

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Aims: In this study, we present an unbiased sample of the earliest stages of massive star formation across 20 deg^2 of the sky.
Methods: Within the region 10° < l < 20° and |b| < 1°, we search the ATLASGAL survey at 870 μm for dense gas condensations. These clumps are carefully examined for indications of ongoing star formation using YSOs from the GLIMPSE source catalog as well as sources in the 24 μm MIPSGAL images, to search for starless clumps. We calculate the column densities as well as the kinematic distances and masses for sources where the v_{lsr} is known from spectroscopic observations.
Results: Within the given region, we identify 210 starless clumps with peak column densities $> 1 \times 10^{23}$ cm^{-2}. For the first time, we identify potential starless clumps on the other side of the Galaxy. The sizes of the clumps range between 0.1 pc and 3 pc with masses between a few tens of $M_\odot$ up to several ten thousands of $M_\odot$. Most of them may form massive stars, but in the 20 deg^2 we only find 14 regions massive enough to form stars more massive than 20 $M_\odot$ and 3 regions with the potential to form stars more massive than 40 $M_\odot$. The slope of the high-mass tail of the clump mass function for clumps on the near side of the Galaxy is $\alpha = 2.2$ and, therefore, Salpeter-like. We estimate the lifetime of the most massive starless clumps to be $(6 \pm 5) \times 10^4$ yr.
Conclusions: The sample offers a uniform selection of starless clumps. In the large area surveyed, we only find a few potential precursors of stars in the excess of 40 $M_\odot$. It appears that the lifetime of these clumps is somewhat shorter than their free-fall times, although both values agree within the errors. In addition, these are ideal objects for detailed studies and follow-up observations.

Accepted by A & A

http://www.mpia.de/homes/tackenberg/tackenberg2012_2column_latest.pdf

Discovery of the youngest molecular outflow associated with an Intermediate-mass protostellar core, MMS 6/OMC-3

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We present sub-arcsecond resolution HCN (4–3) and CO (3–2) observations made with the Submillimeter Array toward an extremely young intermediate-mass protostellar core, MMS 6-main, located in the Orion Molecular Cloud 3 region (OMC-3). We have successfully imaged a compact molecular outflow lobe (∼1500 AU) associated with MMS6-main, which is also the smallest molecular outflow ever found in the intermediate-mass protostellar cores. The dynamical time scale of this outflow is estimated to be <100 yr. The line width dramatically increases downstream at the end of the molecular outflow ($\Delta v \sim 25$ km s^{-1}), and clearly shows the bow-shock type velocity structure. The estimated outflow mass ($\sim 10^{-4}$ $M_\odot$) and outflow size are approximately 2-4 orders and 1-3 orders of magnitude smaller, while the outflow force ($\sim 10^{-4}$ $M_\odot$ km s^{-1} yr^{-1}) is similar, as compared to the other molecular outflows studied in OMC-2/3. These results show that MMS 6-main is a protostellar core at the earliest evolutionary stage, most likely shortly after the second core formation.

Accepted by ApJL

http://arxiv.org/abs/1112.4596

Emission Mechanism of "Green Fuzzies" in High-mass Star Forming Regions

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The Infrared Array Camera (IRAC) on the *Spitzer Space Telescope* has revealed that a number of high-mass protostars are associated with extended mid-infrared emission, particularly prominent at 4.5-μm. These are called "Green Fuzzy" emission or "Extended Green Objects". We present color analysis of this emission toward six nearby (d=2–3 kpc) well-studied high-mass protostars and three candidate high-mass protostars identified with the Spitzer GLIMPSE survey. In our color-color diagrams most of the sources show a positive correlation between the [3.6]-[4.5] and [3.5]-[5.8] colors along the extinction vector in all or part of the region. We compare the colors with those of scattered continuum associated with the low-mass protostar L 1527, modeled scattered continuum in cavities, shocked emission associated with low-mass protostars, modeled H_2 emission for thermal and fluorescent cases, and modeled PAH emission. Of the emission mechanisms discussed above, scattered continuum provides the simplest explanation for the observed linear correlation. In this case, the color variation within each object is attributed to different foreground extinctions at different positions.
Alternative possible emission mechanisms to explain this correlation may be a combination of thermal and fluorescent H_2 emission in shocks, and a combination of scattered continuum and thermal H_2 emission, but detailed models or spectroscopic follow-up are required to further investigate this possibility. Our color-color diagrams also show possible contributions from PAHs in two objects. However, none of our sample show clear evidence for PAH emission directly associated with the high-mass protostars, several of which should be associated with ionizing radiation. This suggests that those protostars are heavily embedded even at mid-infrared wavelengths.

Accepted by Astrophysical Journal

A Hot Gap Around Jupiter's Orbit in the Solar Nebula

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The Sun was an order of magnitude more luminous during the first few hundred thousand years of its existence, due in part to the gravitational energy released by material accreting from the Solar nebula. If Jupiter was already near its present mass, the planet's tides opened an optically-thin gap in the nebula. We show using Monte Carlo radiative transfer calculations that sunlight absorbed by the nebula and re-radiated into the gap raised temperatures well above the sublimation threshold for water ice, with potentially drastic consequences for the icy bodies in Jupiter's feeding zone. Bodies up to a meter in size were vaporized within a single orbit if the planet was near its present location during this early epoch. Dust particles lost their ice mantles, and planetesimals were partially to fully devolatilized, depending on their size. Scenarios in which Jupiter formed promptly, such as those involving a gravitational instability of the massive early nebula, must cope with the high temperatures. Enriching Jupiter in the noble gases through delivery trapped in clathrate hydrates will be more difficult, but might be achieved by either forming the planet much further from the star, or capturing planetesimals at later epochs. The hot gap resulting from an early origin for Jupiter also would affect the surface compositions of any primordial Trojan asteroids.

Accepted by the Astrophysical Journal

http://arxiv.org/abs/1110.4166

Finding proto-spectroscopic binaries: Precise multi-epoch radial velocities of 7 protostars in ρ Ophiuchus

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The formation of spectroscopic binaries (SB) may be a natural byproduct of star formation. The early dynamical evolution of multiple stellar systems after the initial fragmentation of molecular clouds leaves characteristic imprints on the properties of young, multiple stars. The discovery and the characterization of the youngest SB will allow us to infer the mechanisms and timescales involved in their formation. Our work aims to find spectroscopic companions around young stellar objects (YSO). We present a near-IR high-resolution (R $\sim$ 60000) multi-epoch radial velocity survey of 7 YSO in the star forming region (SFR) ρ Ophiuchus. The radial velocities of each source were derived using a two-dimensional cross-correlation function, using the zero-point established by the Earth's atmosphere as reference. More than 14 spectral lines in the CO $\Delta\nu$ = (0-2) bandhead window were used in the cross-correlation against LTE atmospheric models to compute the final results. We found that the spectra of the protostars in our sample agree well with the predicted stellar photospheric profiles, indicating that the radial velocities derived are indeed of stellar nature. Three of the targets analyzed exhibit large radial velocity variations during the three observation epochs. These objects - pending further confirmation and orbital characteristics - may become the first evidence for proto-spectroscopic binaries, and will provide important constraints on their formation. Our preliminary binary fraction (BF) of $\sim$71% (when merging our results with those of previous studies) is in line with the notion that multiplicity is very high at young ages and therefore a byproduct of star formation.

Accepted by Astronomy and Astrophysics

Photoevaporating Proplyd-like objects in Cygnus OB2

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We report the discovery of ten proplyd-like objects in the vicinity of the massive OB association Cygnus OB2. They were discovered in IPHAS Hα images and are clearly resolved in broad-band HST/ACS, near-IR and *Spitzer* mid-IR images. All exhibit the familiar tadpole shape seen in photoevaporating objects such as the Orion proplyds, with a bright ionization front at the head facing the central cluster of massive stars, and a tail stretching in the opposite direction. Many also show secondary ionization fronts, complex tail morphologies or multiple heads. We consider the evidence that these are either proplyds or 'evaporating gaseous globules' (EGGs) left over from a fragmenting molecular cloud, but find that neither scenario fully explains the observations. Typical sizes are 50,000–100,000 AU, larger than the Orion proplyds, but in agreement with the theoretical scaling of proplyd size with distance from the ionizing source. These objects are located at projected separations of $\sim$6–14 pc from the OB association, compared to $\sim$0.1 pc for the Orion proplyds, but are clearly being photoionized by the $\sim$65 O-type stars in Cyg OB2. Central star candidates are identified in near- and mid-IR images, supporting the proplyd scenario, though their large sizes and notable asymmetries is more consistent with the EGG scenario. A third possibility is therefore considered, that these are a unique class of photoevaporating partially-embedded young stellar objects that have survived the destruction of their natal molecular cloud. This has implications for the properties of stars that form in the vicinity of massive stars.

Accepted by ApJL

http://arxiv.org/abs/1201.2404

The Carina Flare: What can fragments in the wall tell us?

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$^{13}CO(J=2–1)$ and $C^{18}O(J=2–1)$ observations of the molecular cloud G285.90+4.53 (Cloud 16) in the Carina Flare supershell (GSH287+04-17) with the APEX telescope are presented. With an algorithm DENDROFIND we identify 51 fragments and compute their sizes and masses. We discuss their mass spectrum and interpret it as being the result of the shell fragmentation process described by the pressure assisted gravitational instability - PAGI. We conclude that the explanation of the clump mass function needs a combination of gravity with pressure external to the shell.

Accepted by A&A

http://arxiv.org/abs/1111.4391v2

The discovery based on GLIMPSE data of a protostar driving a bipolar outflow

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We report the discovery based on GLIMPSE data of a proto-stellar system driving a bipolar outflow . The bipolar outflow closely resembles the shape of an hourglass in the infrared. The total luminosity of $L_{total} = 5507$ L$_{\odot}$, derived from IRAS fluxes, indicates the ongoing formation of a massive star in this region. The spectral energy distribution (SED) of the driving source is fitted with an online SED fitting tool, which results in a spectral index of about 1.2. This, along with the presence of a bipolar outflow, suggests the detection of a Class I protostar. The driving source indicates prominent infrared excesses in color-color diagrams based on archived 2MASS and GLIMPSE data, which is in line with an early evolutionary stage of the system.

Accepted by Astronomy & Astrophysics

http://arxiv.org/abs/1201.3453

Circumstellar Environments around the Youngest Protostars: Interferometric Observations and Modeling

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Ph.D degree awarded: Oct 2011

This thesis presents observations and modeling of nearby embedded sources in the earliest stage of protostellar evolution, i.e., Class 0 young stellar objects, using interferometric data of the Berkeley-Illinois-Maryland Association array (BIMA) and the Combined Array for Research in Millimeter-wave Astronomy (CARMA). Protostars form through gravitational collapse inside their natal envelopes, and these circumstellar envelopes contain valuable information about the physical processes of star formation. In this thesis, both molecular lines and dust continuum are utilized to investigate the nature of the collapsing envelopes. In particular, I focus on the isolated edge-on low-mass protostar L1157. While a large-scale ($\sim$20,000 AU) flattened envelope is detected in both the N_2H^+ line and the 8 μm extinction perpendicular to the outflow orientation, the dust continuum observed by CARMA shows spherical structures at scales between $\sim 10^2$ and $\sim 10^3$ AU. The N_2H^+ observations not only reveal the outer envelope that is too dim to be detected in dust continuum, but they also unveil the kinematic structures of the flattened envelope. The dust continuum is compared with theoretical collapse models using radiative transfer calculation and Bayesian inference. The modeling techniques, as well as the associated uncertainties, are detailed. The results show that a power-law envelope model with a density index $p \sim 2$ provides a better fit to the observations than the simple Shu model or the commonly-used Terebey-Shu-Cassen model. Furthermore, I discuss the implications of the modeling results on the dust grain properties and the constraints they place on the youngest circumstellar disk embedded inside the envelope.

A Comparison of Protostars in Diverse Star-Forming Environments

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Star formation occurs in a variety of environments, from massive star forming clouds like Orion, to low-mass clouds like Ophiuchus, and in more clustered and more distributed regions within clouds as well. It is not yet well understood how the environment (the density and temperature of the surrounding gas) in which a star forms affects the properties i.e. mass, multiplicity, of the resulting star. This work investigates the youngest stars, which exist at or very near their birthplace, and examines the question, "How does Environment Affect Protostar Luminosity?" To assess this question, protostar candidates are identified in ten star-forming clouds, particularly clouds within 1 kpc of the sun including the relatively nearby regions of Serpens, Perseus, Ophiuchus, Chamaeleon, Lupus, Taurus, Orion, Cep OB3, and Mon R2, which combined host over 700 protostar candidates, and the massive star forming region Cygnus-X at a distance of 1.4kpc, which hosts over 2000 protostar candidates. Mid-infrared photometry from the Two-Micron All Sky Survey (*2MASS*) J, H, and K_s bands and *Spitzer* 3.6, 4.5, 5.8, 8.0, and 24 μm bands are used to identify the protostar candidates. In the nearby clouds (within 1 kpc) sources saturated at 24 μm are fit using a modified point-spread function (PSF) flux extraction technique. The photometry of these sources is used to create spectral energy distributions (SEDs) from 1 - 24 μm. A new technique is developed to estimate the bolometric luminosities of protostars from their 1-24 μm photometry. Estimations of the bolometric luminosities for protostar candidates are combined to create luminosity functions for each cloud. Contamination due to edge-on disks, reddened Class II sources, and galaxies are considered and removed from luminosity functions. The luminosity functions of the clouds which form high-mass stars (Orion, Cep OB3, Mon R2, and Cygnus-X) peak near 1 $L_{\odot}$ and have a tail that extends to luminosities above 100 $L_{\odot}$. The luminosity functions of the clouds which do not form high-mass stars do not show a common trend and some do not have significant peaks above the completeness limit. The low and high mass clouds show distinctly different protostellar luminosity functions. Luminosity functions are compared for populations of protostars in regions of higher stellar density and lower stellar density within each cloud. In Orion and Cygnus-X, the two clouds with the largest samples of protostars, luminosity functions of protostars in crowded regions are significantly different from luminosity functions of protostars in regions of lower stellar density. Additionally, the most luminous protostars in both of these clouds are in environments with higher stellar density. The differences between the luminosity functions of protostar ensembles in high and low stellar density regions may indicate differences in the emerging initial mass functions (IMFs) of the stars in these two environments.

IAU Symposium 293

Formation, Detection, and Characterization of Habitable Extrasolar Planets

In conjunction with the 28th IAU General Assembly, August 27-31, 2012, Beijing, China

MEETING WEB SITE: http://www.ifa.hawaii.edu/iau293

MOTIVATION:
The past few years have witnessed significant developments in extrasolar planetary science. Several Earth-like planets and super-Earths have been detected in the habitable zones of their host stars and more than 1200 planetary candidates have been announced. On the theoretical front, these discoveries have triggered extensive research on the formation, dynamical evolution, interior dynamics, and atmospheric characteristics of extrasolar habitable planets. The IAU symposium 293 will bring together scientists from around the world to present new discoveries, and discuss ideas on the formation, detection, and characterization of extrasolar habitable planets. The conference will cover the topics on:

- Methods of detecting habitable planets and mass determination
- Models of the formation of terrestrial/habitable planets
- Water on Earth and in other Solar System bodies
- Processes affecting close-in planets (tides, tidal-locking, radiation)
- Habitability and habitable zone
- Interior dynamics of habitable planets
- Atmospheric models and habitability
- Planetary magnetic fields and their connection to habitability
- Prospects for the detection of biosignatures
- State of current searches for habitable planets
- Future prospects for the detection of extrasolar habitable planets
- Habitability in extreme planetary systems (multiple planets, binary stars, moons,Trojan planets)

Registration

- Early registration deadline: February 29, 2012
- Regular registration: March 1 - August 10, 2012
- On-site registration: August 19 - 26, 2012
- To see the registration fees and to register go to the symposium website.

Abstracts

Contributed talks and posters are welcome and encouraged.

Abstract submission deadline : February 29, 2012

Travel Support

The IAU is offering a limited number of grants to support participation at the XXVIII IAU General Assembly. For more information, see the symposium website.

NASA Astrobiology Institute is also offering a limited number of travel grants to US-based participants. To apply, send an email to iau293@ifa.hawaii.edu. Note that you are required to register and submit an abstract. The deadline is February 29.

For questions and more information contact Nader Haghighipour at nader@ifa.hawaii.edu

The Astrochemical Universe unveiled with Herschel

European Week of Astronomy and Space Science, Symposium 2
July 2nd and 3rd, 2012, Rome (Italy)
http://www.ast.leeds.ac.uk/ewass12/

Motivation

Since its launch in 2009, the Herschel Space Observatory has unveiled the far-IR window with its high sensitive instrumentation, collecting spectra of important molecules towards a variety of different objects: from comets to protoplanetary disks; from the diffuse interstellar medium and photodissociation regions (PDRs) to dense cloud cores; from star forming regions to the circumstellar environment of evolved stars; from local to early-universe galaxies. In doing so, new molecular species have been discovered; unbiased spectral surveys have unveiled an extraordinary rich chemistry; high spectral resolution line profiles of hydrates and important coolants such as water and carbon monoxide have revealed complex chemical/physical processes and shocked material. In summary, Herschel has emphasized the crucial role of astrochemistry in the whole astrophysical community. It is now time to summarize and compare the results obtained in different environments and to discuss their interpretation with the available models, with the aim of advancing our understanding of astrochemical processes in the universe.

Scientific Program

This symposium consists of 5 blocks focused on Herschel spectroscopic and modelling results in different environments, plus one final block where astrochemical models will be presented and discussed. Schematically:

Block 1: *Solar System and Evolved Stars*

Block 2: *The Interstellar Medium and Photodissociation Regions*

Block 3: *Star Forming Regions*

Block 4: *Protoplanetary disks*

Block 5: *External Galaxies*

Block 6: *Astrochemical models*

The six sections will allow different communities to present their major results and discuss together common problems linked to the interpretation of Herschel observations. The final block will be dedicated to the data interpretation and available models. Here, open questions, major problems and future developments for data interpretation techniques and chemical/physical models will be jointly discussed.

Confirmed Invited Speakers

Simon Bruderer, Sylvie Cabrit, Stephanie Cazaux, Cecilia Ceccarelli, Jose Cernicharo, Leen Decin, Maryvonne Gerin, Javier Goicoechea, Paul Hartogh, Michiel Hogerheijde, Inga Kamp, Lars Kristensen, Edo Loenen, Gwendolyn Meeus, Eckhard Sturm, Mario Tafalla, Serena Viti.

Scientific Organizing Committee

Paola Caselli (Chair) – School of Physics and Astronomy, University of Leeds, Leeds, United Kingdom
Frank Helmich – SRON Netherlands Institute for Space Research, Groningen, The Netherlands
Brunella Nisini – INAF-Osservatorio Astronomico di Roma, Monteporzio Catone, Italy
Ewine van Dishoeck – Max-Planck-Institut für extraterrestrische Physik, Garching, Germany; Leiden Observatory, Leiden University, Leiden, The Netherlands

50 Years of Brown Dwarfs: from Theoretical Prediction to Astrophysical Studies

International Conference on Brown Dwarfs at Ringberg Castle, Oct 21-24, 2012

This workshop will take place exactly 50 years after the theoretical prediction of the existence of brown dwarfs, i.e. of degenerate objects just not massive enough to sustain stable hydrogen fusion. The exploration of brown dwarfs has seen tremendous progress over the last years since the first discoveries in the 90ies. How brown dwarfs form, however, is still one of the main open questions in the theory of star formation. A key role to answer this question play brown dwarfs as members of binary and multiple systems. Steadily improving instrumental performance led to the discovery of companions around brown dwarfs down to planetary masses, to size (radii) and dynamical mass determinations, and to statistically significant samples of very low-mass binaries. These detailed empirical characterizations of brown dwarfs enable us to test and calibrate increasingly sophisticated models of internal structure, atmosphere, and formation of substellar objects.

The Ringberg workshop will open with a celebration of the 50th anniversary of Shiv Kumars's theoretical prediction of brown dwarfs and proceed to explore the origin of brown dwarfs with a focus on brown dwarf binaries. The aim is to foster a close link between observational binary studies (RV and direct imaging, incl. individual benchmark systems) and theories in the field of brown dwarf formation. The program will include invited review talks on the main topics as well as contributed talks. We cordially invite the community for abstract submissions.

Location: The conference will take place at the nice venue of Ringberg castle, which is located south of Munich, Germany, in the Bavarian Alps.

Conference web page: http://www.mpia.de/homes/joergens/ringberg2012.html

Registration deadline: April 15, 2012. The number of participants is limited to 70.

SOC: Viki Joergens, Isabelle Baraffe, Gibor Basri, Wolfgang Brandner, Adam Burgasser, Cathie Clarke, Thomas Henning, Ralf Klessen, Keivan Stassun

Moving ... ??

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