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Abstracts of recently accepted papers

The dispersal of protoplanetary disks around binary stars

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I present models of disk evolution around young binary stars. I show that the primary factor in determining circumbinary disk lifetimes is the rate of disk photoevaporation. I also find that photoevaporative clearing leaves a signature on the distribution of circumbinary disk lifetimes, with a sharp increase in disk lifetimes for binary separations $a < 0.3$ –1AU. Observations of young binary stars can therefore be used to test models of disk evolution, and I show that current data set a strong upper limit to the rate of on-going photoevaporation ($< 10^{-9}M_{\odot}\text{yr}^{-1}$). Finally I discuss the implications of these results for planet formation, and suggest that circumbinary planets around close ($a < 1$ AU) binaries should be relatively common.

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<http://arxiv.org/abs/1209.0779>

Orion Revisited - I. The massive cluster in front of the Orion Nebula Cluster

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The aim of this work is to characterize the stellar population between Earth and the Orion A molecular cloud where the well known star formation benchmark Orion Nebula Cluster (ONC) is embedded. We use the denser regions the Orion A cloud to block optical background light, effectively isolating the stellar population in front of it. We then use a multi-wavelength observational approach to characterize the cloud's foreground stellar population. We find that there is a rich stellar population in front of the Orion A cloud, from B-stars to M-stars, with a distinct 1) spatial distribution, 2) luminosity function, and 3) velocity dispersion from the reddened population inside the Orion A cloud. The spatial distribution of this population peaks strongly around NGC 1980 (iota Ori) and is, in all likelihood, the extended stellar content of this poorly studied cluster. We infer an age of $\sim 4 - 5$ Myr for NGC 1980 and estimate a cluster population of the order of 2000 stars, which makes it one of the most massive clusters in the entire Orion complex. This newly found population overlaps significantly with what is currently assumed to be the ONC and the L1641N populations, and can make up for more than 10-20% of what is currently taken in the literature as the ONC population (30-60% if the Trapezium cluster is removed from consideration). What is currently taken in the literature as the ONC is then a mix of several intrinsically different populations, namely: 1) the youngest population, including the Trapezium cluster and ongoing star formation in the dense gas inside the nebula, 2) the foreground population, dominated by the NGC 1980 cluster, and 3) the poorly constrained population of foreground and background Galactic field stars. Our results support a scenario where the ONC and L1641N are not directly associated with NGC 1980, i.e., they are not the same population emerging from its parental cloud, but are instead distinct overlapping populations. The nearest massive star formation region and the template for massive star and cluster formation models is then substantially

contaminated by the foreground stellar population of the massive NGC 1980 cluster, formed about 4–5 Myr ago in a different, but perhaps related, event in the larger Orion star formation complex. This result calls for a revision of most of the observables in the benchmark ONC region (e.g., ages, age spread, cluster size, mass function, disk frequency, etc.).

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On the evolution of irradiated turbulent clouds: A comparative study between modes of triggered star-formation

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Gas within molecular clouds (MCs) is turbulent and unevenly distributed. Interstellar shocks such as those driven by strong fluxes of ionising radiation (IR) profoundly affect MCs. While small dense MCs exposed to a strong flux of IR have been shown to implode due to radiation-driven shocks, a phenomenon called *radiation driven implosion*, larger MCs, however, are likely to survive this flux which in fact, may produce new star-forming sites within these clouds. Here we examine this hypothesis using the Smoothed Particle Hydrodynamics (SPH) algorithm coupled with a ray-tracing scheme that calculates the position of the ionisation-front at each timestep. We present results from simulations performed for three choices of IR-flux spanning the range of fluxes emitted by a typical B-type star to a cluster of OB-type stars. The extent of photo-ablation, of course, depends on the strength of the incident flux and a strong flux of IR severely ablates a MC. Consequently, the first star-formation sites appear in the dense shocked layer along the edges of the irradiated cloud. Radiation-induced turbulence readily generates dense filamentary structure within the photo-ablated cloud although several new star-forming sites also appear in some of the densest regions at the junctions of these filaments. Prevalent physical conditions within a MC play a crucial role in determining the mode, i.e., filamentary as compared to isolated pockets, of star-formation, the timescale on which stars form and the distribution of stellar masses. The probability density functions (PDFs) derived for irradiated clouds in this study are intriguing due to their resemblance with those presented in a recent census of irradiated MCs. Furthermore, irrespective of the nature of turbulence, the protostellar mass-functions (MFs) derived in this study follow a power-law distribution. When turbulence within the cloud is driven by a relatively strong flux of IR such as that emitted by a massive O-type star or a cluster of such stars, the MF approaches the canonical form due to Salpeter, and even turns-over for protostellar masses smaller than $\sim 0.2 M_{\odot}$.

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The nearby population of M-dwarfs with WISE: A search for warm circumstellar dust

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Circumstellar debris disks are important because of their connection to planetary systems. An efficient way to identify these systems is through their infrared excess. Most studies so far concentrated on early-type or solar-type stars, but less effort has gone into investigating M dwarfs.

We characterize the mid-infrared photometric behavior of M dwarfs and search for infrared excess in nearby M dwarfs taken from the volume-limited RECONS sample using data from the WISE satellite and the 2MASS catalog. Our sample consists of 85 sources encompassing 103 M dwarfs. We derive empirical infrared colors from these data and discuss their errors. Based on this, we check the stars for infrared excess and discuss the minimum excess we would be able to detect.

Other than the M8.5 dwarf SCR 1845-6357 A, where the excess is produced by a known T6 companion, we detect no excesses in any of our sample stars. The limits we derive for the 22 μ m excess are slightly higher than the usual detection limit of ~ 10 -15% for Spitzer studies, but including the 12 μ m band and the [12] – [22] color in our analysis

allows us to derive tight constraints on the fractional dust luminosity L_{dust}/L_* . We show that this result is consistent with M dwarf excesses in the mid-infrared being as frequent as excesses around earlier-type stars. The low detection rate of $0_{-0.0}^{+1.3}\%$ we derive for our sample could be an age effect. We also present a tentative excess detection at $22\mu\text{m}$ around the known cold debris disk M dwarf AU Mic, which is not part of our statistical sample.

There is still no clear detection of a mid-infrared excess around any old (≥ 30 Myr) main-sequence M dwarf. It is unclear whether this is due to a different dust evolution around M dwarfs or whether this is an age effect combined with the difficulties involved in searching M dwarfs for infrared excesses. A significantly larger sample of well-studied M dwarfs is required to solve this question.

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On the structure of molecular clouds

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We show that the inter-cloud Larson scaling relation between mean volume density and size $\rho \propto R^{-1}$, which in turn implies that mass $M \propto R^2$, or that the column density N is constant, is an artifact of the observational methods used. Specifically, setting the column density threshold near or above the peak of the column density probability distribution function N -pdf ($N \sim 10^{21} \text{ cm}^{-2}$) produces the Larson scaling as long as the N -pdf decreases rapidly at higher column densities. We argue that the physical reasons behind local clouds to have this behavior are that (1) this peak column density is near the value required to shield CO from photodissociation in the solar neighborhood, and (2) gas at higher column densities is rare because it is susceptible to gravitational collapse into much smaller structures in specific small regions of the cloud. Similarly, we also use previous results to show that if instead a threshold is set for the volume density, the density will appear to be constant, implying thus that $M \propto R^3$. Thus, the Larson scaling relation does not provide much information on the structure of molecular clouds, and does not imply either that clouds are in Virial equilibrium, or have a universal structure. We also show that the slope of the $M - R$ curve for a single cloud, which transitions from near-to-flat values for large radii to $\alpha = 2$ as a limiting case for small radii, depends on the properties of the N -pdf.

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A Disk-Wind Model for the Near-Infrared Excess Emission in Protostars

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Protostellar systems, ranging from low-luminosity classical T Tauri and Herbig Ae stars to high-luminosity Herbig Be stars, exhibit a near-infrared (NIR) excess in their spectra that is dominated by a bump in the monochromatic luminosity with a peak near 3 microns. The bump can be approximated by a thermal emission component of temperature ~ 1500 K that is of the order of the sublimation temperature of interstellar dust grains. In the currently popular “puffed-up rim” scenario, the bump represents stellar radiation that propagates through the optically thin inner region of the surrounding accretion disk and is absorbed and reemitted by the dust that resides just beyond the dust sublimation radius r_{sub} . However, this model cannot account for the strongest bumps measured in these sources, and it predicts a pronounced secondary bounce in the interferometric visibility curve that is not observed. In this paper we present an alternative interpretation, which attributes the bump to reemission of stellar radiation by dust that is uplifted from the disk by a centrifugally driven wind. Winds of this type are a leading candidate for the origin of the strong outflows associated with protostars, and there is observational evidence for disk winds originating on scales $\sim r_{\text{sub}}$. Using a newly constructed Monte Carlo radiative transfer code and focusing on low-luminosity sources,

we show that this model can account for the NIR excess emission even in bright Herbig Ae stars such as AB Auriga and MWC 275, and that it successfully reproduces the basic features of the visibilities measured in these protostars. We argue that a robust dusty outflow in these sources could be self-limiting — through shielding of the stellar FUV photons — to a relatively narrow launching region between r_{sub} and $\sim 2r_{\text{sub}}$. We also suggest that the NIR and scattered-light variability exhibited by a source like MWC 275 can be attributed in this picture to the uplifting of dust clouds from the disk.

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3D-PDR: A new three-dimensional astrochemistry code for treating Photodissociation Regions

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Photodissociation regions (PDRs) define the transition zone between an ionized and a dark molecular region. They consist of neutral gas which interacts with far-ultraviolet radiation and are characterized by strong infrared line emission. Various numerical codes treating one-dimensional PDRs have been developed in the past, simulating the complexity of chemical reactions occurring and providing a better understanding of the structure of a PDR. In this paper we present the three-dimensional code, 3D-PDR, which can treat PDRs of arbitrary density distribution. The code solves the chemistry and the thermal balance self-consistently within a given three-dimensional cloud. It calculates the total heating and cooling functions at any point in a given PDR by adopting an escape probability method. It uses a HEALPix-based ray-tracing scheme to evaluate the attenuation of the far-ultraviolet radiation in the PDR and the propagation of the far-infrared/submm line emission out of the PDR. We present benchmarking results and apply 3D-PDR to i) a uniform-density spherical cloud interacting with a plane-parallel external radiation field, ii) a uniform-density spherical cloud interacting with a two-component external radiation field, and iii) a cometary globule interacting with a plane-parallel external radiation field. We find that the code is able to reproduce the benchmarking results of various other one-dimensional numerical codes treating PDRs. We also find that the accurate treatment of the radiation field in the fully three-dimensional treatment of PDRs can in some cases lead to different results when compared to a standard one-dimensional treatment.

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H₂O line mapping at high spatial and spectral resolution: *Herschel* observations of the VLA 1623 outflow

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Apart from being an important coolant, water is known to be a tracer of high-velocity molecular gas. Recent models predict relatively high abundances behind interstellar shockwaves. The dynamical and physical conditions of the water emitting gas, however, are not fully understood yet. Using the *Herschel* Space Observatory, it is now possible to observe water emission from supersonic molecular outflows at high spectral and spatial resolution. Several molecular outflows from young stars are currently being observed as part of the WISH (Water In Star-forming regions with *Herschel*) key program. We aim to determine the abundance and distribution of water, its kinematics, and the physical conditions of the gas responsible for the water emission. The observed line profile shapes help us understand the dynamics in molecular outflows. We mapped the VLA 1623 outflow, in the ground-state transitions of *o*-H₂O, with the HIFI and PACS instruments. We also present observations of higher energy transitions of *o*-H₂O and *p*-H₂O obtained with HIFI and PACS towards selected outflow positions. From comparison with non-LTE radiative transfer calculations, we estimate the physical parameters of the water emitting regions. The observed water emission line profiles vary over the mapped area. Spectral features and components, tracing gas in different excitation conditions, allow us to constrain the density and temperature of the gas. The water emission originates in a region where temperatures are comparable to that of the warm H₂ gas ($T \gtrsim 200$ K). Thus, the water emission traces a gas component significantly warmer than the gas responsible for the low-*J* CO emission. The water column densities at the CO peak positions are low, i.e. $N(\text{H}_2\text{O}) \simeq (0.03 - 10) \times 10^{14} \text{ cm}^{-2}$. The water abundance with respect to H₂ in the extended outflow is estimated at $X(\text{H}_2\text{O}) < 1 \times 10^{-6}$, significantly lower than what would be expected from most recent shock models. The H₂O emission traces a gas component moving at relatively high velocity compared to the low-*J* CO emitting gas. However, other dynamical quantities such as the momentum rate, energy, and mechanical luminosity are estimated to be the same, independent of the molecular tracer used, CO or H₂O.

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On the massive young stellar object AFGL4176: High-spatial-resolution multi-wavelength observations and modeling

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Deeply embedded and at distances of several kiloparsecs, massive young stellar objects (MYSOs) present numerous challenges for observation and study. In this work, we present spatially-resolved observations of one MYSO, AFGL 4176, together with survey and literature data, ranging from interferometric observations with VLTI/MIDI in the mid-infrared, to single-dish Herschel measurements in the far-infrared, and sub-millimeter data from APEX. We consider this spatially-resolved, multi-wavelength data set in terms of both radiative transfer and geometric models. We find that the observations are well described by one-dimensional models overall, but there are also substantial deviations from spherical symmetry at scales of tens to hundreds of astronomical units, which are revealed by the mid-infrared interferometric measurements. We use a multiple-component, geometric modeling approach to explain the mid-infrared emission on scales of tens to hundreds of astronomical units, and find the MIDI measurements are well described by a model consisting of a one-dimensional Gaussian halo and an inclined ($\theta = 60^\circ$) circumstellar disk extending out to several hundred astronomical units along a position angle of 160° . Finally, we compare our results both with previous models of this source, and with those of other MYSOs, and discuss the present situation with mid-infrared interferometric observations of massive stars.

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Locating the Trailing Edge of the Circumbinary Ring in the KH 15D System

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Following two years of complete occultation of both stars by its opaque circumbinary ring, the binary T Tauri star KH 15D has abruptly brightened again during apastron phases, reaching $I = 15$ mag. Here, we show that the brightening is accompanied by a change in spectral class from K6/K7 (the spectral class of star A) to \sim K1, and a bluing of the system in $V - I$ by about 0.3 mag. A radial velocity measurement confirms that, at apastron, we are now seeing direct light from star B, which is more luminous and of earlier spectral class than star A. Evidently, the trailing edge of the occulting screen has just become tangent to one ansae of star B's projected orbit. This confirms a prediction of the precession models, supports the view that the tilted ring is self-gravitating, and ushers in a new era of the system's evolution that should be accompanied by the same kind of dramatic phenomena observed from 1995-2009. It also promotes KH 15D from a single-lined to a double-lined eclipsing binary, greatly enhancing its value for testing pre-main sequence models. The results of our study strengthen the case for truncation of the outer ring at around 4 AU by a sub-stellar object such as an extremely young giant planet. The system is currently at an optimal configuration for detecting the putative planet and we urge expedient follow-up observations.

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First detection of water vapor in a pre-stellar core

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Water is a crucial molecule in molecular astrophysics as it controls much of the gas/grain chemistry, including the formation and evolution of more complex organic molecules in ices. Pre-stellar cores provide the original reservoir of material from which future planetary systems are built, but few observational constraints exist on the formation of water and its partitioning between gas and ice in the densest cores. Thanks to the high sensitivity of the Herschel Space Observatory, we report on the first detection of water vapor at high spectral resolution toward a dense cloud on the verge of star formation, the pre-stellar core L1544. The line shows an inverse P-Cygni profile, characteristic of gravitational contraction. To reproduce the observations, water vapor has to be present in the cold and dense central few thousand AU of L1544, where species heavier than Helium are expected to freeze-out onto dust grains, and the ortho:para H_2 ratio has to be around 1:1 or larger. The observed amount of water vapor within the core (about

$1.5 \times 10^{-6} M_{\odot}$) can be maintained by Far-UV photons locally produced by the impact of galactic cosmic rays with H_2 molecules. Such FUV photons irradiate the icy mantles, liberating water vapor in the core center. Our Herschel data, combined with radiative transfer and chemical/dynamical models, shed light on the interplay between gas and solids in dense interstellar clouds and provide the first measurement of the water vapor abundance profile across the parent cloud of a future solar-type star and its potential planetary system.

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The Herschel and IRAM CHESS spectral surveys of the protostellar shock L1157-B1: fossil deuteration

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We present the first study of deuteration towards the protostellar shock L1157-B1, based on spectral surveys performed with the Herschel-HIFI and IRAM 30-m telescopes. The L1157 outflow is driven by a low-mass Class 0 protostar and is considered the prototype of the so-called chemically active outflows. The young (2000 yr), bright blue-shifted bow shock, B1, is an ideal laboratory for studying the gas chemically enriched by the release of dust mantles due to the passage of a shock.

A total of 12 emission lines (up to $E_u = 63$ K) of CH_2DOH , $HDCO$, and DCN are detected. In addition, two lines of NH_2D and HDO are tentatively reported. To estimate the deuteration we also extracted from our spectral survey emission lines of non-deuterated isotopologues ($^{13}CH_3OH$, $H_2^{13}CO$, $H^{13}CN$, $H_2^{13}CO$, and NH_3). We infer higher deuteration fractions for CH_3OH ($D/H = 0.2\text{--}2 \cdot 10^{-2}$) and H_2CO ($5\text{--}8 \cdot 10^{-3}$) than for H_2O ($0.4\text{--}2 \cdot 10^{-3}$), HCN ($\sim 10^{-3}$) and ammonia ($\leq 3 \cdot 10^{-2}$).

The measurement of deuteration of water, formaldehyde and methanol in L1157-B1 provides a fossil record of the gas before it was shocked by the jet driven by the protostar. A comparison with gas-grain models indicates that the gas passed through a low density ($\leq 10^3 \text{ cm}^{-3}$) phase, during which the bulk of water ices formed, followed by a phase of increasing density, up to $3 \times 10^4 \text{ cm}^{-3}$, during which formaldehyde and methanol ices formed.

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LAMP: The Long-term Accretion Monitoring Program of T Tauri stars in Chamaeleon-I

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We present the results of a variability study of accreting young stellar objects in the Chamaeleon I star-forming region which is based on ~ 300 high resolution optical spectra from the multi-object fibre spectrograph FLAMES/GIRAFFE at the ESO/VLT. Twenty five objects with spectral types from G2-M5.75 were observed 12 times over the course of 15 months. Using the emission lines $H\alpha$ (6562.81 \AA) and $Ca II$ (8662.1 \AA) as accretion indicators we found 10 accreting and 15 non-accreting objects. We derived accretion rates for all accretors in the sample using the $H\alpha$ equivalent width,

H α 10% width and the CaII equivalent width. The mean amplitude of variations in derived accretion rate from H α equivalent width was ~ 0.37 dex, from CaII equivalent width ~ 0.83 dex and from H α 10% width ~ 1.11 dex. Based on the large amplitude of variations in accretion rates derived from the H α 10% width with respect to the other diagnostics, we do not consider it to be a reliable accretion rate estimator. Taking the variations in H α equivalent width and CaII equivalent width accretion rates to be closer to the true value, they suggest that the spread which has been found around the accretion rate to stellar mass relation is not due to the variability of individual objects on time-scales of weeks to ~ 1 year.

From these variations we can also infer that the accretion rates are stable within < 0.37 dex over time-scales of less than 15 months. A major portion of the accretion variability was found to occur on less than the shortest time-scales in our observations, 8-25 days, which is comparable with the rotation periods of these young stellar objects. This could be an indication that what we are probing is spatial structure in the accretion flows, and also suggests that observations on time-scales of \sim a couple of weeks are sufficient to limit the total extent of accretion rate variations in typical young stars.

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Characterizing a cluster's dynamic state using a single epoch of radial velocities

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Context: Radial velocity measurements can be used to constrain the dynamical state of a stellar cluster. However, for clusters with velocity dispersions smaller than a few km/s the observed radial velocity distribution tends to be dominated by the orbital motions of binaries rather than the stellar motions through the potential well of the cluster. Aims. Our goal is to characterize the intrinsic velocity distribution of a cluster from a single epoch of radial velocity data even for a cluster with a velocity dispersion of a fraction of a km/s.

Method: We investigate a maximum likelihood procedure, which was pioneered separately by Odenkirchen et al. (2002) and Kleyna et al. (2002). Assuming a period, mass ratio, and eccentricity distribution for the binaries in the observed cluster this procedure fits a dynamical model describing the velocity distribution for the single stars and center of masses of the binaries, simultaneously with the radial velocities caused by binary orbital motions, using all the information available in the observed velocity distribution. We test the capability of this procedure to reproduce the velocity dispersion of an observed cluster, using radial velocity data of an open cluster and Monte Carlo simulations.

Results: We find that the fits to the intrinsic velocity distribution depend only weakly on the binary properties assumed, so the uncertainty in the fitted parameters tends to be dominated by statistical uncertainties. Based on a large suite of Monte Carlo simulations we provide an estimate of how these statistical uncertainties vary with the velocity dispersion, binary fraction, and the number of observed stars, which can be used to estimate the sample size needed to reach a specific accuracy. Finally we test the method on the well-studied open cluster NGC 188, showing that it can successfully reproduce a velocity dispersion of only 0.5 km/s using a single epoch of the multi-epoch radial velocity data.

Conclusions: If the binary period, mass ratio, and eccentricity distribution of the observed stars are roughly known, this procedure can be used to correct for the effect of binary orbital motions on an observed velocity distribution. This allows for the study of the dynamical state of a stellar cluster with a small velocity dispersion from a single epoch of radial velocity data.

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Interstellar matter and star formation in W5-E - A Herschel view

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Aims: We identify the young stellar objects (YSOs) present in the vicinity of the W5-E HII region, and study the influence of this HII region on the star formation process in its surrounding molecular material.

Methods: W5-E has been observed with the Herschel-PACS and -SPIRE photometers, as part of the HOBYS key program; maps have been obtained at 100 μm , 160 μm , 250 μm , 350 μm , and 500 μm . The dust temperature and column density have been obtained by fitting spectral energy distributions (SEDs). Point sources have been detected and measured using PSF photometry with DAOPHOT.

Results: The dust temperature map shows a rather uniform temperature, in the range 17.5 K – 20 K in the dense condensations or filaments, in the range 21 K – 22 K in the photodissociation regions (PDRs), and in the range 24 K – 31 K in the direction of the ionized regions. The values in the column density map are rather low, everywhere lower than 10^{23} cm^{-2} , and of the order of a few 10^{21} cm^{-2} in the PDRs.

About 8000 M_{\odot} of neutral material surrounds the ionized region, which is low with respect to the volume of this HII region; we suggest that the exciting stars of the W5-E, W5-W, Sh 201, A and B HII regions formed along a dense filament or sheet rather than inside a more spherical cloud.

Fifty point sources have been detected at 100 μm . Most of them are Class 0/I YSOs. The SEDs of their envelopes have been fitted using a modified blackbody model. These envelopes are cold, with a mean temperature of 15.7 ± 1.8 K. Their masses are in the range $1.3 M_{\odot} - 47 M_{\odot}$. Eleven of these point sources are candidate Class 0 YSOs. Twelve of these point sources are possibly at the origin of bipolar outflows detected in this region. None of the YSOs contain a massive central object, but a few may form a massive star as they have both a massive envelope and also a high envelope accretion rate. Most of the Class 0/I YSOs are observed in the direction of high column density material, for example in the direction of the massive condensations present at the waist of the bipolar Sh 201 HII region or enclosed by the bright-rimmed cloud BRC14. The overdensity of Class 0/I YSOs on the borders of the HII regions present in the field strongly suggests that triggered star formation is at work in this region but, due to insufficient resolution, the exact processes at the origin of the triggering are difficult to determine.

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The Lesser Role of Shear in Galactic Star Formation: Insight from the Galactic Ring Survey

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We analyse the role played by shear in regulating star formation in the Galaxy on the scale of individual molecular clouds. The clouds are selected from the $^{13}\text{CO } J = 1 - 0$ line of the Galactic Ring Survey. For each cloud, we estimate the shear parameter which describes the ability of density perturbations to grow within the cloud. We find that for almost all molecular clouds considered, there is no evidence that shear is playing a significant role in opposing the effects of self-gravity. We also find that the shear parameter of the clouds does not depend on their position in the Galaxy. Furthermore, we find no correlations between the shear parameter of the clouds with several indicators of their star formation activity. No significant correlation is found between the shear parameter and the star formation efficiency of the clouds which is measured using the ratio of the massive young stellar objects luminosities, measured in the Red MSX survey, to the cloud mass. There are also no significant correlations between the shear parameter and the fraction of their mass that is found in denser clumps which is a proxy for their clump formation efficiency, nor with their level of fragmentation expressed in the number of clumps per unit mass. Our results strongly suggest

that shear is playing only a minor role in affecting the rates and efficiencies at which molecular clouds convert their gas into dense cores and thereafter into stars.

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Interpretation of the Veiling of the Photospheric Spectrum for T Tauri Stars in Terms of an Accretion Model.

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The problem on heating the atmospheres of T Tauri stars by radiation from an accretion shock has been solved. The structure and radiation spectrum of the emerging so-called hot spot have been calculated in the LTE approximation. The emission not only in continuum but also in lines has been taken into account for the first time when calculating the spot spectrum. Comparison with observations has shown that the strongest of these lines manifest themselves as narrow components of helium and metal emission lines, while the weaker ones decrease significantly the depth of photospheric absorption lines, although until now, this effect has been thought to be due to the emission continuum alone. The veiling by lines changes the depth of different photospheric lines to a very different degree even within a narrow spectral range. Therefore, the nonmonotonic wavelength dependence of the degree of veiling r found for some CTTS does not suggest a nontrivial spectral energy distribution of the veiling continuum. In general, it makes sense to specify the degree of veiling r only by providing the set of photospheric lines from which this quantity was determined. We show that taking into account the contribution of lines to the veiling of the photospheric spectrum can cause the existing estimates of the accretion rate onto T Tauri stars to decrease by several times, with this being also true for stars with a comparatively weakly veiled spectrum. Neglecting the contribution of lines to the veiling can also lead to appreciable errors in determining the effective temperature, interstellar extinction, radial velocity, and $v \sin i$.

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On the origin of elemental abundances in the terrestrial planets

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The abundances of elements in the Earth and the terrestrial planets provide the initial conditions for life and clues as to the history and formation of the Solar System. We follow the pioneering work of Bond et al. (2010), and combine circumstellar disk models, chemical equilibrium calculations and dynamical simulations of planet formation to study the bulk composition of rocky planets. We use condensation sequence calculations to estimate the initial abundance of solids in the circumstellar disk with properties determined from time dependent theoretical models. We combine this with dynamical simulations of planetesimal growth that trace the solids during the planet formation process and which include the effects of gravitational and hydrodynamical mixing. We calculate the elemental abundances in the resulting rocky planets and explore how these vary with the choice of disk model and the initial conditions within the Solar Nebula.

Although certain characteristics of the terrestrial planets in the Solar System could be reproduced, none of our models could reproduce the abundance properties of all the planets. We found that the choice of the initial planetesimal disk mass and of the disk model has a significant effect on composition gradients. Disk models that give higher pressure and temperature result in larger variations in the bulk chemical compositions of the resulting planets due to inhomogeneities in the element abundance profiles and due to the different source regions of the planets in the dynamical simulations. We observed a trend that massive planets and planets with relatively small semi-major axes are more sensitive to these variations than smaller planets at larger radial distance. Only these large variations in the simulated chemical abundances can potentially explain the diverse bulk composition of the Solar System planets,

whereas Mercury's bulk composition can not be reproduced in our approach.

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<http://www.itp.uzh.ch/~selser/publications/elser2012.pdf>

On fan-shaped cold MHD winds from Keplerian accretion discs

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We investigate under which conditions cold, fan-shaped winds can be steadily launched from thin (Keplerian) accretion discs. Such winds are magneto-centrifugal winds launched from a thin annulus in the disc, along open magnetic field lines that fan out above the disc. In principle, such winds could be found in two situations: (1) at the interface between an inner Jet Emitting Disc, which is itself powering magneto-centrifugally driven winds, and an outer standard accretion disc; (2) at the interface between an inner closed stellar magnetosphere and the outer standard accretion disc. We refer to Terminal or T-winds to the former kind and to Magnetospheric or M-winds to the latter.

The full set of resistive and viscous steady state MHD equations are analyzed for the disc (the annulus), which allow us to derive general expressions valid for both configurations. We find that, under the framework of our analysis, the only source of energy able to power any kind of fan-shaped winds is the viscous transport of rotational energy coming below the inner radii. Using standard local α prescriptions for the anomalous (turbulent) transport of angular momentum and magnetic fields in the disc, we derive the strength of the transport coefficients that are needed to steadily sustain the global configuration. It turns out that, in order for these winds to be dynamically relevant and explain observed jets, the disc coefficients must be far much larger than values expected from current knowledge of turbulence occurring inside proto-stellar discs.

Either the current view on MHD turbulence must be deeply reconsidered or steady-state fan-shaped winds are never realized in Nature. The latter hypothesis seems to be consistent with current numerical simulations.

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Optical photometric GTC/OSIRIS observations of the young massive association Cygnus OB2

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In order to fully understand the gravitational collapse of molecular clouds, the star formation process and the evolution of circumstellar disks, these phenomena must be studied in different Galactic environments with a range of stellar contents and positions in the Galaxy. The young massive association Cygnus OB2, in the Cygnus-X region, is an unique target to study how star formation and the evolution of circumstellar disks proceed in the presence of a large number of massive stars. We present a catalog obtained with recent optical observations in r , i , z filters with OSIRIS, mounted on the 10.4 m GTC telescope, which is the deepest optical catalog of Cyg OB2 to date.

The catalog consist of 64157 sources down to $M = 0.15 M_{\odot}$ at the adopted distance and age of Cyg OB2. A total of 38300 sources have good photometry in all three bands. We combined the optical catalog with existing X-ray data of this region, in order to define the cluster locus in the optical diagrams. The cluster locus in the $r - i$ vs. $i - z$

diagram is compatible with an extinction of the optically selected cluster members in the $2.64^m < A_V < 5.57^m$ range. We derive an extinction map of the region, finding a median value of $A_V = 4.33^m$ in the center of the association, decreasing toward the north-west. In the color-magnitude diagrams, the shape of the distribution of main sequence stars is compatible with the presence of an obscuring cloud in the foreground at $\sim 850 \pm 25 pc$ from the Sun.

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Formation of proto-clusters and star formation within clusters: apparent universality of the initial mass function ?

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It is believed that the majority of stars form in clusters. Therefore it is likely that the gas physical conditions that prevail in forming clusters largely determine the properties of stars that form in particular, the initial mass function. We develop an analytical model to account for the formation of low-mass clusters and the formation of stars within clusters. The formation of clusters is determined by an accretion rate, the virial equilibrium as well as energy and thermal balance. For this latter, both molecular and dust cooling are considered using published rates. The star distribution is computed within the cluster using the physical conditions inferred from this model and the Hennebelle & Chabrier theory. Our model reproduces well the mass-size relation of low mass clusters (up to few $\simeq 10^3 M_\odot$ of stars corresponding to about five times more gas) and an initial mass function that is *i*) very close to the Chabrier IMF, *ii*) weakly dependent on the mass of the clusters, *iii*) relatively robust to (i.e. not too steeply dependent on) variations of physical quantities such as accretion rate, radiation, and cosmic ray abundances. The weak dependence of the mass distribution of stars on the cluster mass results from the compensation between varying clusters densities, velocity dispersions, and temperatures that are all inferred from first physical principles. This constitutes a possible explanation for the apparent universality of the IMF within the Galaxy although variations with the local conditions may certainly be observed.

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Detection of the simplest sugar, glycolaldehyde, in a solar-type protostar with ALMA

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Glycolaldehyde (HCOCH_2OH) is the simplest sugar and an important intermediate in the path toward forming more complex biologically relevant molecules. In this paper we present the first detection of 13 transitions of glycolaldehyde around a solar-type young star, through Atacama Large Millimeter Array (ALMA) observations of the Class 0 protostellar binary IRAS 16293-2422 at 220 GHz (6 transitions) and 690 GHz (7 transitions). The glycolaldehyde lines have their origin in warm (200–300 K) gas close to the individual components of the binary. Glycolaldehyde co-exists with its isomer, methyl formate (HCOOCH_3), which is a factor 10–15 more abundant toward the two sources. The data also show a tentative detection of ethylene glycol, the reduced alcohol of glycolaldehyde. In the 690 GHz data, the seven transitions predicted to have the highest optical depths based on modeling of the 220 GHz lines all show red-shifted absorption profiles toward one of the components in the binary (IRAS16293B) indicative of infall and emission at the

systemic velocity offset from this by about $0.2''$ (25 AU). We discuss the constraints on the chemical formation of glycolaldehyde and other organic species – in particular, in the context of laboratory experiments of photochemistry of methanol-containing ices. The relative abundances appear to be consistent with UV photochemistry of a $\text{CH}_3\text{OH-CO}$ mixed ice that has undergone mild heating. The order of magnitude increase in line density in these early ALMA data illustrate its huge potential to reveal the full chemical complexity associated with the formation of solar system analogs.

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Testing the universality of star formation - II. Comparing separation distributions of nearby star-forming regions and the field

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We have measured the multiplicity fractions and separation distributions of seven young star-forming regions using a uniform sample of young binaries. Both the multiplicity fractions and separation distributions are similar in the different regions. A tentative decline in the multiplicity fraction with increasing stellar density is apparent, even for binary systems with separations too close (19–100 AU) to have been dynamically processed. The separation distributions in the different regions are statistically indistinguishable over most separation ranges, and the regions with higher densities do not exhibit a lower proportion of wide (300–620 AU) relative to close (62–300 AU) binaries as might be expected from the preferential destruction of wider pairs. Only the closest (19–100 AU) separation range, which would be unaffected by dynamical processing, shows a possible difference in separation distributions between different regions. The combined set of young binaries, however, shows a distinct difference when compared to field binaries, with a significant excess of close (19–100 AU) systems among the younger binaries. Based on both the similarities and differences between individual regions, and between all seven young regions and the field, especially over separation ranges too close to be modified by dynamical processing, we conclude that multiple star formation is not universal and, by extension, the star formation process is not universal.

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RW Aur A from the X-Wind Point of View: General Features

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In this paper, the RW Aur A microjet is studied from the point of view of X-wind models. The archived *HST*/STIS spectra of optical forbidden lines [O I], [S II], and [N II] from RW Aur A, taken in Cycle 8 with seven parallel slits along the jet axis, spaced at $0''.07$ apart, were analyzed. Images, position-velocity diagrams, and line ratios among the species were constructed, and compared with synthetic observations generated by selected solutions of the X-wind. Prominent features arising in a steady-state X-wind could be identified within the convolved images, full-widths at half maxima and high-velocity peaks on both of the redshifted and blueshifted jets. The well-known asymmetric velocity profiles of the opposite jets are built into the selected models. We discuss model selections within the existing uncertainties of stellar parameters and inclination angle of the system. In this framework, the mass-loss rates that were inferred to be decreasing along the jet axis in the literature are the results of slowly decreasing excitation conditions and electron density profiles. Despite the apparent asymmetry in terminal velocities, line intensities and mass-loss rates,

the average linear momenta from the opposite sides of the jet are actually balanced. These previously hard-to-explain features of the asymmetric RW Aur A jet system now find a different but self-consistent interpretation within the X-wind framework.

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Star formation activity in the Galactic H II region Sh2-297

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We present a multiwavelength study of the Galactic H II region Sh2-297, located in Canis Major OB1 complex. Optical spectroscopic observations are used to constrain the spectral type of ionizing star HD 53623 as B0V. The classical nature of this H II region is affirmed by the low values of electron density and emission measure, which are calculated to be 756 cm^{-3} and $9.15 \times 10^5 \text{ cm}^{-6} \text{ pc}$ using the radio continuum observations at 610 and 1280 MHz, and VLA archival data at 1420 MHz. To understand local star formation, we identified the young stellar object (YSO) candidates in a region of area $\sim 7.5' \times 7.5'$ centered on Sh2-297 using grism slitless spectroscopy (to identify the H α emission line stars), and near infrared (NIR) observations. NIR YSO candidates are further classified into various evolutionary stages using color-color (CC) and color-magnitude (CM) diagrams, giving 50 red sources ($H - K > 0.6$) and 26 Class II-like sources. The mass and age range of the YSOs are estimated to be $\sim 0.1-2 M_{\odot}$ and $0.5-2 \text{ Myr}$ using optical ($V/V-I$) and NIR ($J/J-H$) CM diagrams. The mean age of the YSOs is found to be $\sim 1 \text{ Myr}$, which is of the order of dynamical age of 1.07 Myr of the H II region. Using the estimated range of visual extinction (1.1–25 mag) from literature and NIR data for the region, spectral energy distribution (SED) models have been implemented for selected YSOs which show masses and ages to be consistent with estimated values. The spatial distribution of YSOs shows an evolutionary sequence, suggesting triggered star formation in the region. The star formation seems to have propagated from the ionizing star towards the cold dark cloud LDN1657A located west of Sh2-297.

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<http://xxx.lanl.gov/pdf/1209.3420>; A version with full resolution figures is available at <http://www.tifr.res.in/~ojha/ms-297.pdf>

Centimeter continuum observations of the northern head of the HH 80/81/80N jet: revising the actual dimensions of a parsec scale jet

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We present 6 and 20 cm JVLA/VLA observations of the northern head of the HH 80/81/80N jet, one of the largest

collimated jet systems known so far, aimed to look for knots further away than HH 80N, the northern head of the jet. Aligned with the jet and 10 arcmin northeast of HH 80N, we found a radio source not reported before, with a negative spectral index similar to that HH 80, HH 81 and HH 80N. The fit of a precessing jet model to the knots of the HH 80/81/80N jet, including the new source, shows that the position of this source is close to the jet path resulting from the modeling. If the new source belongs to the HH 80/81/80N jet, its derived size and dynamical age are 18.4 pc and $> 9 \times 10^3$ yr, respectively. If the jet is symmetric, its southern lobe would expand beyond the cloud edge resulting in an asymmetric appearance of the jet. Based on the updated dynamical age, we speculate on the possibility that the HH 80/81/80N jet triggered the star formation observed in a dense core found ahead of HH 80N, which shows signposts of interaction with the jet. These results indicate that pc scale radio jets can play a role on the stability of dense clumps and the regulation of star formation in the molecular cloud.

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The *Spitzer* Space Telescope Survey of the Orion A & B Molecular Clouds - Part I: A Census of Dusty Young Stellar Objects and a Study of their Mid-IR Variability

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We present a survey of the Orion A and B molecular clouds undertaken with the IRAC and MIPS instruments onboard *Spitzer*. In total, five distinct fields were mapped covering 14 sq. degrees in five mid-IR bands spanning 3-24 μm . The survey includes the Orion Nebula Cluster, the Lynds 1641, 1630 and 1622 dark clouds, and the NGC 2023, 2024, 2068 and 2071 nebulae. These data are merged with the 2MASS point source catalog to generate a catalog of eight band photometry. We identify 3479 dusty young stellar objects (YSOs) in the Orion molecular clouds by searching for point sources with mid-IR colors indicative of reprocessed light from dusty disks or infalling envelopes. The YSOs are subsequently classified on the basis of their mid-IR colors and their spatial distributions are presented. We classify 2991 of the YSOs as pre-main sequence stars with disks and 488 as likely protostars. Most of the sources were observed with IRAC in 2-3 epochs over 6 months; we search for variability between the epochs by looking for correlated variability in the 3.6 and 4.5 μm bands. We find that 50% of the dusty YSOs show variability. The variations are typically small (~ 0.2 mag.) with the protostars showing a higher incidence of variability and larger variations. The observed correlations between the 3.6, 4.5, 5.8 and 8 μm variability suggests that we are observing variations in the heating of the inner disk due to changes in the accretion luminosity or rotating accretion hot spots.

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Preprints available on <http://arxiv.org/abs/1209.3826>

A higher resolution version (50 MB) of the paper and the Point Source Catalog can be found at:

http://astro1.physics.utoledo.edu/~megeath/Orion/The_Spitzer_Orion_Survey.html

Exploring the Effects of Stellar Rotation and Wind Clearing: Debris Disks Around F Stars

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We have conducted a study of debris disks around F stars in order to explore correlations between rotation, stellar winds, and circumstellar disks. We obtained new 24 μm photometry from Spitzer's Multiband Imaging Photometer for Spitzer (MIPS) camera for a sample of 188 relatively nearby F dwarfs with various rotation rates and optical colors, and combined it with archival MIPS data for 66 more F stars, as well as Wide-field Infrared Survey Explorer (WISE) data for the entire sample, plus 9 more F stars. Based on the objects' $K_s - [24]$ and $[3.4] - [22]$ colors, we identify 22 stars in our sample as having 22 and/or 24 μm excesses above our detection limit, 13 of which are new discoveries. Our overall disk detection rate is 22/263, or 8%, consistent with previous determinations of disk fractions in the Solar neighborhood. While fast rotating stars are expected to have strong winds capable of efficiently removing dust, we find no correlation between rotational velocity and infrared excess. Similarly, we find no significant difference in excess detection rate between late-type F stars, which have convective surfaces, and early-type F stars, which have fully radiative envelopes. However, the essentially unknown range of ages in this sample may be washing out any effects relating rotation, winds, and disks.

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<http://web.ipac.caltech.edu/staff/rebull/research.html>

Substellar-Mass Condensations in Prestellar Cores

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We present combined Submillimeter-Array (SMA) + single-dish images of the (sub)millimeter dust continuum emission toward two prestellar cores SM1 and B2-N5 in the nearest star cluster forming region, ρ Ophiuchus. Our combined images indicate that SM1 and B2-N5 consist of three and four condensations, respectively, with masses of $10^{-2} - 10^{-1}M_{\odot}$ and sizes of a few hundred AU. The individual condensations have mean densities of $10^8 - 10^9 \text{ cm}^{-3}$ and the masses are comparable to or larger than the critical Bonner-Ebert mass, indicating that the self-gravity plays an important role in the dynamical evolution of the condensations. The coalescence timescale of these condensations is estimated to be about 10^4 yr, which is comparable to the local gravitational collapse timescale, suggesting that merging of the condensations, instead of accretion, plays an essential role in the star formation process. These results challenge the standard theory of star formation, where a single, rather featureless prestellar core collapses to form at most a couple of condensations, each of which potentially evolves into a protostar that is surrounded by a rotating disk where planets are created.

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VLT imaging of the β Pictoris gas disk

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Circumstellar debris disks older than a few Myr should be largely devoid of primordial gas remaining from the protoplanetary disk phase. Tracing the origin of observed atomic gas in Keplerian rotation in the edge-on debris disk surrounding the ~ 12 Myr old star β Pictoris requires more detailed information about its spatial distribution than has previously been acquired by limited slit spectroscopy. Especially indications of asymmetries and presence of Ca II gas at high disk latitudes call for additional investigation to exclude or confirm its connection to observed dust structures or suggested cometary bodies on inclined eccentric orbits. We set out to recover a complete image of the Fe I and Ca II gas emission around β Pic by spatially resolved, high-resolution spectroscopic observations to better understand the morphology and origin of the gaseous disk component. The multiple fiber facility FLAMES/GIRAFFE at the Very Large Telescope (VLT), with the large integral-field-unit ARGUS, was used to obtain spatially resolved optical spectra (from 385.9 to 404.8 nm) in four regions covering the northeast and southwest side of the disk. Emission lines from Fe I (at 386.0 nm) and Ca II (at 393.4 and 396.8 nm) were mapped and could be used to fit a parametric function for the disk gas distribution, using a gas-ionisation code for gas-poor debris disks. Both Fe I and Ca II emission are clearly detected, with the former dominating along the disk midplane, and the latter revealing vertically more extended gas. The surface intensity of the Fe I emission is lower but more extended in the northeast (reaching the 210 AU limit of our observations) than in the southwest, while Ca II shows the opposite asymmetry. The modelled Fe gas disk profile shows a linear increase in scale height with radius, and a vertical profile that suggests dynamical interaction with the dust. We also qualitatively demonstrate that the Ca II emission profile can be explained by optical thickness in the disk midplane, and does not require Ca to be spatially separated from Fe.

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Characterizing the dynamical state of star clusters from snapshots of their spatial distributions

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We determine the distribution of stellar surface densities, Σ , from models of static and dynamically evolving star clusters with different morphologies, including both radially smooth and substructured clusters. We find that the Σ distribution is degenerate, in the sense that many different cluster morphologies (smooth or substructured) produce similar cumulative distributions. However, when used in tandem with a measure of structure, such as the Q -parameter, the current spatial and dynamical state of a star cluster can be inferred. The effect of cluster dynamics on the Σ distribution and the Q -parameter is investigated using N -body simulations and we find that, depending on the assumed initial conditions, the Σ distribution can rapidly evolve from high to low densities in less than 5 Myr. This suggests that the Σ distribution can only be used to assess the current density of a star forming region, and provides little information on its initial density. However, if the Σ distribution is used together with the Q -parameter, then information on the amount of substructure can be used as a proxy to infer the amount of dynamical evolution that has taken place. Substructure is erased quickly through dynamics, which can disrupt binary star systems and planets, as well as facilitate dynamical mass segregation. Therefore, dynamical processing in young star forming regions could still be significant, even without currently observed high densities.

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A search for mass segregation of stars and brown dwarfs in ρ Ophiuchi

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We apply two different algorithms to search for mass segregation to a recent observational census of the ρ Ophiuchi star forming region. Firstly, we apply the Λ_{MSR} method, which compares the minimum spanning tree (MST) of a chosen subset of stars to MSTs of random subsets of stars in the cluster, and determine the mass segregation ratio, Λ_{MSR} . Secondly, we apply the $m - \Sigma$ method, which calculates the local stellar surface density around each star and determines the statistical significance of the average surface density for a chosen mass bin, compared to the average surface density in the whole cluster. Using both methods, we find no indication of mass segregation (normal or inverse) in the spatial distribution of stars and brown dwarfs in ρ Ophiuchi. Although ρ Ophiuchi suffers from high visual extinction, we show that a significant mass segregation signature would be detectable, albeit slightly diluted, despite dust obscuration of centrally located massive stars.

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The mass function and dynamical mass of young star clusters: Why their initial crossing-time matters crucially

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We highlight the impact of cluster-mass-dependent evolutionary rates upon the evolution of the cluster mass function during violent relaxation, that is, while clusters dynamically respond to the expulsion of their residual star-forming gas. Mass-dependent evolutionary rates arise when the mean volume density of cluster-forming regions is mass-dependent. In that case, even if the initial conditions are such that the cluster mass function at the end of violent relaxation has the same shape as the embedded-cluster mass function (i.e. infant weight-loss is mass-independent), the shape of the cluster mass function does change transiently *during* violent relaxation. In contrast, for cluster-forming regions of constant mean volume density, the cluster mass function shape is preserved all through violent relaxation since all clusters then evolve at the same mass-independent rate.

On the scale of individual clusters, we model the evolution of the ratio between the dynamical mass and luminous mass of a cluster after gas expulsion. Specifically, we map the radial dependence of the time-scale for a star cluster to return to equilibrium. We stress that fields-of-view a few pc in size only, typical of compact clusters with rapid evolutionary rates, are likely to reveal cluster regions which have returned to equilibrium even if the cluster experienced a major gas expulsion episode a few Myr earlier. We provide models with the aperture and time expressed in units of the initial half-mass radius and initial crossing-time, respectively, so that our results can be applied to clusters with initial densities, sizes, and apertures different from ours.

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Spectral classification and HR diagram of pre-main sequence stars in NGC6530

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Mechanisms involved in the star formation process and in particular the duration of the different phases of the cloud contraction are not yet fully understood. Photometric data alone suggest that objects coexist in the young cluster NGC 6530 with ages from ~ 1 Myr up to 10 Myrs. We want to derive accurate stellar parameters and, in particular, stellar ages to be able to constrain a possible age spread in the star-forming region NGC6530. We used low-resolution spectra taken with VIMOS@VLT and literature spectra of standard stars to derive spectral types of a subsample of 94 candidate members of this cluster. We assign spectral types to 86 of the 88 confirmed cluster members and

derive individual reddenings. Our data are better fitted by the anomalous reddening law with $R_V=5$. We confirm the presence of strong differential reddening in this region. We derive fundamental stellar parameters, such as effective temperatures, photospheric colors, luminosities, masses, and ages for 78 members, while for the remaining 8 YSOs we cannot determine the interstellar absorption, since they are likely accretors, and their V-I colors are bluer than their intrinsic colors. The cluster members studied in this work have masses between 0.4 and $4M_\odot$ and ages between 1-2 Myrs and 6-7 Myrs. We find that the SE region is the most recent site of star formation, while the older YSOs are loosely clustered in the N and W regions. The presence of two distinct generations of YSOs with different spatial distribution allows us to conclude that in this region there is an age spread of 6-7 Myrs. This is consistent with the scenario of sequential star formation suggested in literature.

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Empirical Near Infrared colors for low-mass stars and brown dwarfs in the Orion Nebula Cluster - An empirical Near Infrared isochrone at ~ 1 Myr

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Current atmospheric and evolutionary models for low-mass stars and brown dwarfs rely on approximate assumptions on the physics of the stellar structure and the atmospheric radiative transfer. This leads to biased theoretical predictions on the photospheric Spectral Energy Distributions of these system, especially when applied to low surface gravity objects such as Pre-Main Sequence (PMS) stars, and affects the derivation of stellar parameters from photometric data.

Our main goal is to correct the biases present in the theoretical predictions for the near-IR photometry of low-mass PMS stars. Using empirical intrinsic IR colors, we assess the accuracy of current synthetic spectral libraries and evolutionary models. We investigate how the uncertainty in the intrinsic colors associated with different PMS models affect the derivation of the Initial Mass Function of young clusters from near-IR photometry.

We consider a sample of ~ 300 PMS stars in the Orion Nebula Cluster (age $\simeq 1$ Myr) with well measured luminosities, temperatures and photospheric JHK_S photometry. This sample is used as a benchmark for testing both atmospheric and evolutionary theoretical models.

By analyzing the photospheric colors of our sample of young stars, we find that the synthetic JHK_S photometry provided by theoretical spectral templates for late spectral types ($>K6$) are accurate at the level of ~ 0.2 mag, while colors are accurate at $\lesssim 0.1$ mag. We tabulate the intrinsic photospheric colors, appropriate for the Orion Nebula Cluster, in the range K6-M8.5. They can be conveniently used as templates for the intrinsic colors of other young (age < 5 Myr) stellar clusters.

The theoretically-predicted JHK_S magnitudes of young late type stars do not accurately reproduce the intrinsic ones of the Orion Nebula Cluster members. An empirical correction of the atmospheric templates can fix the discrepancies between expected and observed colors. Still, other biases in the evolutionary models prevent a more robust comparison between observations and theoretical absolute magnitudes. In particular, PMS evolutionary models seem to consistently underestimate the intrinsic near-infrared flux at the very late spectral types, and this may introduce spurious features in the low-mass end of the photometrically-determined Initial Mass Function of young clusters.

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Bipolar jets launched from magnetically diffusive accretion disks. I. Ejection efficiency vs field strength and diffusivity

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We investigate the launching of jets and outflows from magnetically diffusive accretion disks. Using the PLUTO code we solve the time-dependent resistive MHD equations taking into account the disk and jet evolution simultaneously. The main question we address is *which kind of disks do launch jets and which kind of disks do not?* In particular, we study how the magnitude and distribution of the (turbulent) magnetic diffusivity affect mass loading and jet acceleration. We have applied a turbulent magnetic diffusivity based on α -prescription, but have also investigate examples where the scale height of diffusivity is larger than that of the disk gas pressure. We further investigate how the ejection efficiency is governed by the magnetic field strength. Our simulations last for up to 5000 dynamical time scales corresponding to 900 orbital periods of the inner disk. As a general result we observe a continuous and robust outflow launched from the inner part of the disk, expanding into a collimated jet of super fast magneto-sonic speed. For long time scales the disk internal dynamics changes, as due to outflow ejection and disk accretion the disk mass decreases. For magneto-centrifugally driven jets we find that for i) less diffusive disks, ii) a stronger magnetic field, iii) a low poloidal diffusivity, or a iv) lower numerical diffusivity (resolution), the mass loading of the outflow is increased - resulting in more powerful jets with high mass flux. For weak magnetization the (weak) outflow is driven by the magnetic pressure gradient. We consider in detail the advection and diffusion of magnetic flux within the disk and we find that the disk and outflow magnetization may substantially change in time. This may have severe impact on the launching and formation process - an initially highly magnetized disk may evolve into a disk of weak magnetization which cannot drive strong outflows. We further investigate the asymptotic velocity, the jet rotational velocity in respect of the different launching scenarios. We find generally lower jet collimation then previous studies, most probably due to our revised outflow boundary condition.

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Spectral classification of the brightest objects in the galactic star forming region W40

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We present high S/N, moderate resolution near-infrared spectra, as well as 10 micron imaging, for the brightest members of the central stellar cluster in the W40 HII region, obtained using the SpeX and MIRS instruments at NASA's Infrared Telescope Facility. Using these observations combined with archival Spitzer Space Telescope data, we have determined the spectral classifications, extinction, distances, and spectral energy distributions for the brightest members of the cluster. Of the eight objects observed, we identify four main sequence (MS) OB stars, two Herbig Ae/Be stars, and two low-mass young stellar objects. Strong HeI absorption at 1.083 micron in the MS star spectra strongly suggests that at least some of these sources are in fact close binaries. Two out of the four MS stars also show significant infrared excesses typical of circumstellar disks. Extinctions and distances were determined for each MS star by fitting model stellar atmospheres to the SEDs. We estimate a distance to the cluster of between 455 and 535 pc, which agrees well with earlier (but far less precise) distance estimates. We conclude that the late-O star we identify is the dominant source of LyC luminosity needed to power the W40 HII region and is the likely source of the stellar wind that has blown a large (~ 4 pc) pinched-waist bubble observed in wide field mid-IR images. We also suggest that 3.6 cm radio emission observed from some of the sources in the cluster is likely not due to emission from ultra-compact HII regions, as suggested in other work, due to size constraints based on our derived distance to the cluster. Finally, we also present a discussion of the curious source IRS 3A, which has a very strong mid-IR excess (despite its B3 MS classification) and appears to be embedded in a dusty envelope roughly 2700 AU in size.

Catch Me If You Can: Is there a “Runaway-mass” Black Hole in the Orion Nebula Cluster?

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We investigate the dynamical evolution of the Orion Nebula Cluster (ONC) by means of direct N -body integrations. A large fraction of residual gas was probably expelled when the ONC formed, so we assume that the ONC was much more compact when it formed compared to its current size, in agreement with the embedded cluster radius–mass relation from Marks & Kroupa. Hence, we assume that few-body relaxation played an important role during the initial phase of evolution of the ONC. In particular, three body interactions among OB stars likely led to their ejection from the cluster and, at the same time, to the formation of a massive object via “runaway” physical stellar collisions. The resulting depletion of the high-mass end of the stellar mass function in the cluster is one of the important points where our models fit the observational data. We speculate that the runaway-mass star may have collapsed directly into a massive black hole ($M_{\bullet} > 100 M_{\odot}$). Such a dark object could explain the large velocity dispersion of the four Trapezium stars observed in the ONC core. We further show that the putative massive black hole is likely to be a member of a binary system with $\approx 70\%$ probability. In such a case, it could be detected either due to short periods of enhanced accretion of stellar winds from the secondary star during pericentre passages, or through a measurement of the motion of the secondary whose velocity would exceed 10 km s^{-1} along the whole orbit.

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The Circumstellar Disc of AB Aurigae: Evidence for Envelope Accretion at Late Stages of Star Formation?

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The circumstellar disc of AB Aurigae has garnered great attentions due to the apparent existence of spirals at a relatively young stage and also the asymmetric disc traced in thermal dust emission. However, the physical conditions of the spirals are still not well understood. The origin of the asymmetric thermal emission is unclear.

We observe the disc at 230 GHz (1.3 mm) in both continuum and the spectral line 12CO 2-1 with IRAM 30 m, the Plateau de Bure Interferometer and the Submillimeter Array to sample all spatial scales from $0.37''$ to about $50''$. To combine the data obtained from these telescopes, several methods and calibration issues have been checked and discussed.

The 1.3 mm continuum (dust) emission is resolved into inner disc and outer ring. The emission from the dust ring is highly asymmetric in azimuth, with intensity variations by a factor 3. Molecular gas at high velocities traced by the CO line is detected aside the stellar location. The inclination angle of the disc is found to decrease toward the center.

At larger scale, based on the intensity weighted dispersion and the integrated intensity map of 12CO 2-1, four spirals are identified, where two of them are also detected in the near-infrared. The total gas mass of the 4 spirals (M_{spiral}) is $10^{-7} < M_{\text{spiral}} < 10^{-5} M_{\text{sun}}$, which is 3 orders of magnitude smaller than the mass of the gas ring. Surprisingly, the CO gas inside the spiral is apparently counter-rotating with respect to the CO disc and exhibits only small radial motion.

The wide gap, the warped disc, and the asymmetric dust ring, suggest the existence of an undetected companion with a mass of $0.03 M_{\text{sun}}$ at a radius of 45 AU. The different spirals would however require multiple perturbing bodies. While viable from an energetic point of view, this mechanism cannot explain the apparent counter-rotation of the gas in the spirals. Although an hypothetic fly-by cannot be ruled out, the most likely explanation of the AB Aurigae system may be inhomogeneous accretion well above/or below the main disc plane from the remnant envelope, which can explain both the rotation and large scale motions detected with the 30-m image.

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Scenarios to explain extreme Be depletion in solar-like stars: accretion or rotation effects?

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Studies of beryllium abundance in large samples of solar-type stars show a small fraction of extremely beryllium-deficient stars, which challenges our current understanding of light element depletion in these stars. We suggest two possible scenarios that may explain this high level of Be depletion: early accretion and rotational mixing. We show that in both cases, the conditions required to reach the observed level of Be depletion are quite extreme, which explains the very small fraction of detected Be outliers. We suggest that substantial Be depletion can be obtained in stars if they were fast rotators in the past, with high initial rotational velocities and short disc lifetimes. Our analysis suggests that rotational mixing may not be efficient enough to deplete Be in less than 10 Myr. Consequently, the detection of strongly Be-deficient stars in clusters younger than ~ 10 Myr may provide a genuine signature of accretion process and the proof that some protostars may undergo many extreme bursts of accretion during their embedded phases of evolution.

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Molecular line survey of the high-mass star-forming region NGC 6334I with Herschel/HIFI and the SMA

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Aims. We aim at deriving the molecular abundances and temperatures of the hot molecular cores in the high-mass star-forming region NGC 6334I and consequently deriving their physical and astrochemical conditions.

Methods. In the framework of the Herschel guaranteed time key program CHESS (Chemical Herschel Surveys of Star Forming Regions), NGC 6334I is investigated by using the Heterodyne Instrument for the Far-Infrared (HIFI) aboard the Herschel Space Observatory. A spectral line survey is carried out in the frequency range 480–1907 GHz, and further auxiliary interferometric data from the Submillimeter Array (SMA) in the 230 GHz band provide spatial information for disentangling the different physical components contributing to the HIFI spectrum. The spectral

lines in the processed Herschel data are identified with the aid of former surveys and spectral line catalogs. The observed spectrum is then compared to a simulated synthetic spectrum, assuming local thermal equilibrium, and best fit parameters are derived using a model optimization package.

Results. A total of 46 molecules are identified, with 31 isotopologues, resulting in about 4300 emission and absorption lines. High-energy levels ($E_u > 1000$ K) of the dominant emitter methanol and vibrationally excited HCN ($\nu_2 = 1$) are detected. The number of unidentified lines remains low with 75, or $< 2\%$ of the lines detected. The modeling suggests that several spectral features need two or more components to be fitted properly. Other components could be assigned to cold foreground clouds or to outflows, most visible in the SiO and H₂O emission. A chemical variation between the two embedded hot cores is found, with more N-bearing molecules identified in SMA1 and O-bearing molecules in SMA2.

Conclusions. Spectral line surveys give powerful insights into the study of the interstellar medium. Different molecules trace different physical conditions like the inner hot core, the envelope, the outflows or the cold foreground clouds. The derived molecular abundances provide further constraints for astrochemical models.

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Abstracts of recently accepted major reviews

The First Stars

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The first stars to form in the Universe – the so-called Population III stars – bring an end to the cosmological Dark Ages, and exert an important influence on the formation of subsequent generations of stars and on the assembly of the first galaxies. Developing an understanding of how and when the first Population III stars formed and what their properties were is an important goal of modern astrophysical research. In this review, I discuss our current understanding of the physical processes involved in the formation of Population III stars. I show how we can identify the mass scale of the first dark matter halos to host Population III star formation, and discuss how gas undergoes gravitational collapse within these halos, eventually reaching protostellar densities. I highlight some of the most important physical processes occurring during this collapse, and indicate the areas where our current understanding remains incomplete. Finally, I discuss in some detail the behaviour of the gas after the formation of the first Population III protostar. I discuss both the conventional picture, where the gas does not undergo further fragmentation and the final stellar mass is set by the interplay between protostellar accretion and protostellar feedback, and also the recently advanced picture in which the gas does fragment and where dynamical interactions between fragments have an important influence on the final distribution of stellar masses.

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The Formation and Early Evolution of Low-mass Stars and Brown Dwarfs

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The discovery of large numbers of young low-mass stars and brown dwarfs over the last decade has made it possible to investigate star formation and early evolution in a previously unexplored mass regime. In this review, we begin by describing surveys for low-mass members of nearby associations, open clusters, star-forming regions and the methods used to characterize their stellar properties. We then use observations of these populations to test theories of star formation and evolution at low masses. For comparison to the formation models, we consider the initial mass function, stellar multiplicity, circumstellar disks, protostellar characteristics, and kinematic and spatial distributions at birth for low-mass stars and brown dwarfs. To test the evolutionary models, we focus on measurements of dynamical masses and empirical Hertzsprung-Russell diagrams for young brown dwarfs and planetary companions.

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The Initial Distribution of Stars

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Ph.D dissertation directed by: Nate Bastian, Leonardo Testi, Jenny Patience, and Matthew Bate

Ph.D degree awarded: September 2012

The primary focus of my PhD is to quantify the spatial distribution of star-forming environments from optical to radio wavelengths using data from the *Hubble Space Telescope*, the *Very Large Telescope*, the *Spitzer Space Telescope*, the *Herschel Space Observatory*, and the *Caltech Submillimeter Observatory*. Towards the end of my PhD study I have developed theoretical models. With these observational and theoretical avenues I have led a series of research projects to (1) quantify the initial spatial structure of pre-stellar cores and proto-stars, (2) test whether massive stars can form in isolation or not, (3) and develop a theoretical model on how young massive clusters form.

These research projects have been fruitful as my collaborators and I have shown that pre-stellar cores and stars form in a smooth continuum of surface densities from a few to thousands of stars per pc². These two works have important implications on our understanding of what a young stellar cluster is and how star forming environments can evolve to form field star populations or gravitationally bound clusters. In my second study my collaborators and I found evidence for isolated massive star formation in the active star forming region 30 Doradus, in the Large Magellanic Cloud. The result impacts the field of the initial mass function and star formation models. Continuing my work on massive star forming environments my collaborators and I have developed a theoretical model on how young massive clusters form. From the models we argue that feedback energies can be contained by the gravitational potential well of the massive progenitors. Furthermore, we predict the physical properties the massive cluster progenitors in terms of initial gas mass, radii and flux brightness to enable a search for these objects in Galactic plane surveys and upcoming telescopes. Using the common thread of spatial distribution analysis of star formation I describe my future research plans, which entails studies on extragalactic scales in the conclusion.

New Jobs

Postdoc in Star Formation at the University of Geneva

The Department of Astronomy of the University of Geneva, Switzerland, invites applications for a postdoctoral position in star formation related to understanding the structure and evolution of molecular clouds as part of the STARFORM Project, a joint effort of the University of Geneva, the University of Zurich, and the ETH Zurich. STARFORM is a Swiss collaboration aimed at understanding the star formation process from observational, theoretical, and computational points of view. We seek to explore star formation within nearby molecular clouds and in distant galaxies, from small to large scales, using in particular infrared and millimeter observations and state-of-the-art simulations. More information can be found at <http://obswww.unige.ch/wordpress/starform>

The successful candidate will work on millimeter interferometric observations of massive star forming regions, in particular infrared dark clouds, starless cores, and/or high-mass protostellar objects. The candidate is expected to use proprietary and archival data and to develop an observational program as part of the STARFORM project, in collaboration with Dr. Marc Audard at the University of Geneva. The candidate will also collaborate with the STARFORM members and within international collaborations.

The appointment will be for two years, with a possible extension depending on funding availability and performance, starting in Spring 2013 (date negotiable).

Qualified candidates are encouraged to send their application including a CV, a publication list, and a description of research experience and interests (the latter maximum 3 pages). The application, as well as three letters of reference (sent directly by the referees) should be sent by e-mail to Marc.Audard@unige.ch before Jan 1, 2013.

Guild Research Fellowship in Star Formation at University of Central Lancashire

The University of Central Lancashire is making a strategically important investment in the future of its academic staff with the introduction of the Guild Research Fellowships.

These five-year positions will support outstanding individuals who are not far into their academic careers. Each Fellow will have a PhD, have already shown the ability to conduct world-class research and will be demonstrating the clear potential to be an international leader in their respective disciplines in the near future. Normally, the appointment will be on the Senior Research Fellow scale (Grade I, 39257-45486) and will have a start-up research fund of 15,000. Our aim with the Guild Research Fellowships is to grow the next generation of UCL's leading academics.

Star Formation is targetted for one of these Fellowships.

Please note job profiles and application forms will be available from 31st August 2012 to 15th October 2012. See:

www.uclan.ac.uk/research/guild_research_fellowships.php

Email dward-thompson@uclan.ac.uk for more information.

Meetings

Exploring the Formation and Evolution of Planetary Systems

2-7 June 2013

Victoria, BC, Canada

<http://www.iaus299.org>

<https://www.facebook.com/events/376085279113847/>

Email: iaus-299@di.utoronto.ca

This is the second announcement for the 299th Symposium of the International Astronomical Union (IAU), “Exploring the Formation and Evolution of Planetary Systems”, co-organized by the Dunlap Institute for Astronomy & Astrophysics and the National Research Council of Canada. The goal of this meeting is to bring together the communities studying the formation of planets in protoplanetary discs and those who study evolved exoplanet systems. The timing is chosen to highlight the first results from a number of new facilities and instruments which will impact these fields.

Topics will include:

- Observations of protoplanetary discs, debris discs and exoplanets
- Planetesimal and planet formation
- Exoplanet atmospheres and interior structure
- Dynamics in planetary systems: migration, multiplicity and planet-disc interactions

The meeting will be held at the Victoria Conference Centre in the heart of picturesque Victoria, British Columbia, on Canada’s Pacific coast. Local attractions include whale watching, wine tours, the world-famous Butchart Gardens, and the Dominion Astrophysical Observatory. Excellent beaches, diving, camping and hiking are all within a day’s drive from Victoria.

Invited Speakers (confirmed):

Richard Alexander (Leicester, UK), Sean Andrews (CfA, USA), Beth Biller (MPIA, Heidelberg, Germany), Rosemary Mardling (Monash, Australia), Antonella Natta (DIAS, Ireland), Roman Rofikov (Princeton, USA), and Mark Wyatt (IoA, Cambridge, UK). The public lecture will be given by Debra Fischer of Yale University.

Registration

Registration is now open. The early registration period will end on 7 December 2012. Registration will then continue until 31 March 2013, or until we reach our maximum number of registrants (200). The registration fee is \$300 Cdn during early registration and will rise to \$400 Cdn after 7 Dec 2012. The first 70 students registering during early registration will receive a \$120 Cdn grant to offset the cost of registration.

The registration fee includes general conference items (program, USB key with the program included), the opening night reception (incl. drink ticket), the poster session (incl. drink ticket) and public lecture. The fee also includes the mandatory purchase of the Proceedings of the symposium.

Financial Assistance

In keeping with the spirit of the IAU Symposia, the costs of the meeting have been kept as low as possible. In addition, financial assistance in the form of IAU Support Grants is available to aid attendance. Anyone requiring support is encouraged to apply. Students may of course apply for more support than the registration offset grant mentioned above. The deadline for submission of grant applications to the Science Organizing Committee is 7 December 2012; forms and directions are available on the symposium website.

Abstract Submission

We are now accepting submissions for posters and contributed talks. Our schedule includes space for 40 contributed talks of 20 minutes each; in addition, we have sufficient poster space that any registrant not giving a talk is guaranteed a poster place. All contributions will be included in the proceedings. We plan to have prizes for the best student presentations at the meeting.

Information about Visas, travel, accommodation and the conference banquet are also now available on the conference website.

Key Dates

- 14 Sept 2012: Early Registration Opens
- 7 Dec 2012: Deadline for Early Registration and Applications for IAU Support Grants
- 31 March 2013: Deadline for Registration and Abstract Submission
- 2 June 2013: Evening Reception/Symposium Begins
- 3-7 June 2013: Symposium

For more information, please visit our website, facebook event entry or email the conference. We hope to see you in Victoria in June 2013!

Brenda Matthews

LOC Chair, on behalf of the LOC and SOC

Astrochemistry in the ALMA era

Workshop in Copenhagen – January 28th-31st, 2013

ALMA is expected to allow a significant step forward in our understanding of the processes regulating the physical and chemical structure of the interstellar medium in a variety of astrophysical environments from star and planet forming regions to late type stars and galaxies. It is now time to review the scientific output of the many Herschel and ground based molecular line surveys conducted in recent years, present ALMA early science results and identify the outstanding scientific questions that can be addressed with ALMA.

In the workshop we expect to review and discuss the results of ongoing surveys especially in view of the need of high angular resolution requirements for proper analysis and line identification. The full ALMA array will provide the much needed image fidelity and sensitivity to determine whether complex molecules originate at the same or different locations. Another key topic that we will address are the relative merits of performing ALMA complete spectral scans versus a more careful selection of spectral regions to answer the specific scientific questions. At the workshop we will also discuss the progress with the advanced data analysis tools for line surveys that have been and are being developed in Europe in the framework of the Herschel and ALMA preparations initiatives and with the support of Astronet (ARTIST, CASSIS and CATS), as well as those developed elsewhere. Finally, we will review recent results from laboratory astrophysics and what is needed for interpreting incoming data - e.g., in terms more complete line lists and collision rate coefficients.

For further information and registration see the conference website: <http://youngstars.nbi.dk/alma2013>. Limited travel support will be available for participants through support from ESO and Radionet. If needed please contact the organizers at [alma2013 -at- nbi.dk](mailto:alma2013-at-nbi.dk).

SOC: Jes Jørgensen, Susanne Aalto, Edwin Bergin, Cecilia Ceccarelli, Peter Schilke, Leonardo Testi, Ewine van Dishoeck