

# THE STAR FORMATION NEWSLETTER

*An electronic publication dedicated to early stellar evolution and molecular clouds*

No. 231 — 23 Mar 2012

Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

## *Abstracts of recently accepted papers*

### **Deserts and pile-ups in the distribution of exoplanets due to photoevaporative disc clearing**

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We present models of giant planet migration in evolving protoplanetary discs. We show that disc clearing by EUV photoevaporation can have a strong effect on the distribution of giant planet semi-major axes. During disc clearing planet migration is slowed or accelerated in the region where photoevaporation opens a gap in the disc, resulting in “deserts” where few giant planets are found and corresponding “pile-ups” at smaller and larger radii. However, the precise locations and sizes of these features are strong functions of the efficiency of planetary accretion, and therefore also strongly dependent on planet mass. We suggest that photoevaporative disc clearing may be responsible for the pile-up of  $\sim$ Jupiter-mass planets at  $\sim$  1AU seen in exoplanet surveys, and show that observations of the distribution of exoplanet semi-major axes can be used to test models of both planet migration and disc clearing.

Accepted by MNRAS (Letters).

<http://arxiv.org/abs/1202.5554> or <http://www.astro.le.ac.uk/users/rda5/publications.html>

### **A Hybrid Scenario for the Formation of Brown Dwarfs and Very Low Mass Stars**

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We present a calculation of protostellar disk formation and evolution in which gaseous clumps (essentially, the first Larson cores formed via disk fragmentation) are ejected from the disk during the early stage of evolution. This is a universal process related to the phenomenon of ejection in multiple systems of point masses. However, it occurs in our model entirely due to the interaction of compact, gravitationally-bound gaseous clumps and is free from the smoothing-length uncertainty that is characteristic of models using sink particles. Clumps that survive ejection span a mass range of  $0.08\text{--}0.35 M_{\odot}$ , and have ejection velocities  $0.8 \pm 0.35 \text{ km s}^{-1}$ , which are several times greater than the escape speed. We suggest that, upon contraction, these clumps can form substellar or low-mass stellar objects with notable disks, or even close-separation very-low-mass binaries. In this hybrid scenario, allowing for ejection of clumps rather than finished protostars/proto-brown-dwarfs, disk formation and the low velocity dispersion of low-mass objects are naturally explained, while it is also consistent with the observation of isolated low-mass clumps that are ejection products. We conclude that clump ejection and the formation of isolated low mass stellar and substellar objects is a common occurrence, with important implications for understanding the initial mass function, the brown dwarf desert, and the formation of stars in all environments and epochs.

Accepted by The Astrophysical Journal

<http://arxiv.org/abs/1203.0274>

# Discovery of A Binary System in IRAM 04191+1522

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We present high angular resolution observations of the Class 0 protostar IRAM 04191+1522, using the Submillimeter Array (SMA). The SMA 1.3 mm continuum images reveal within IRAM 04191+1522 two distinct sources with an angular separation of  $7.8 \pm 0.2''$ . The two continuum sources are located in the southeast-northwest direction, with total gas masses of  $\sim 0.011 M_{\odot}$  and  $\sim 0.005 M_{\odot}$ , respectively. The southeastern source, associated with an infrared source seen in the *Spitzer* images, is the well-known Class 0 protostar with a bolometric luminosity of  $\sim 0.08 L_{\odot}$ . The newly-discovered northwestern continuum source is not visible in the *Spitzer* images at wavelengths from 3.6 to 70  $\mu\text{m}$ , and has an extremely low bolometric luminosity ( $< 0.03 L_{\odot}$ ). Complementary IRAM  $\text{N}_2\text{H}^+$  (1–0) data that probe the dense gas in the common envelope suggest that the two sources were formed through the rotational fragmentation of an elongated dense core. Furthermore, comparisons between IRAM 04191+1522 and other protostars suggest that most cores with binary systems formed therein have ratios of rotational energy to gravitational energy  $\beta_{\text{rot}} > 1\%$ . This is consistent with theoretical simulations and indicates that the level of rotational energy in a dense core plays an important role in the fragmentation process.

Accepted by ApJ Letters

<http://arxiv.org/abs/1202.2807>

# Bridging the gap: disk formation in the Class 0 phase with ambipolar diffusion and Ohmic dissipation

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*Context.* Ideal magnetohydrodynamical (MHD) simulations have revealed catastrophic magnetic braking in the protostellar phase, which prevents the formation of a centrifugal disk around a nascent protostar.

*Aims.* We determine if non-ideal MHD, including the effects of ambipolar diffusion and Ohmic dissipation determined from a detailed chemical network model, will allow for disk formation at the earliest stages of star formation.

*Methods.* We employ the axisymmetric thin-disk approximation in order to resolve a dynamic range of 9 orders of magnitude in length and 16 orders of magnitude in density, while also calculating partial ionization using up to 19 species in a detailed chemical equilibrium model. Magnetic braking is applied to the rotation using a steady-state approximation, and a barotropic relation is used to capture the thermal evolution.

*Results.* We resolve the formation of the first and second cores, with expansion waves at the periphery of each, a magnetic diffusion shock, and prestellar infall profiles at larger radii. Power-law profiles in each region can be understood analytically. After the formation of the second core, the centrifugal support rises rapidly and a low-mass disk of radius  $\approx 10 R_{\odot}$  is formed at the earliest stage of star formation, when the second core has mass  $\sim 10^{-3} M_{\odot}$ . The mass-to-flux ratio is  $\sim 10^4$  times the critical value in the central region.

*Conclusions.* A small centrifugal disk can form in the earliest stage of star formation, due to a shut-off of magnetic braking caused by magnetic field dissipation in the first core region. There is enough angular momentum loss to allow the second collapse to occur directly, and a low-mass stellar core to form with a surrounding disk. The disk mass and size will depend upon how the angular momentum transport mechanisms within the disk can keep up with mass infall onto the disk. Accounting only for direct infall, we estimate that the disk will remain  $\leq 10$  AU, undetectable even by ALMA, for  $\approx 4 \times 10^4$  yr, representing the early Class 0 phase.

Accepted by Astronomy & Astrophysics

<http://arxiv.org/abs/1112.3801>

# Star formation towards the Scutum tangent region and the effects of Galactic environment

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By positional matching to the catalogue of Galactic Ring Survey molecular clouds, we have derived distances to 793 Bolocam Galactic Plane Survey (BGPS) sources out of a possible 806 located within the region defined by Galactic longitudes  $l = 28.5^\circ$  to  $31.5^\circ$  and latitudes  $|b| \leq 1^\circ$ . This section of the Galactic Plane contains several major features of Galactic structure at different distances, mainly mid-arm sections of the Perseus and Sagittarius spiral arms and the tangent of the Scutum-Centaurus arm, which is coincident with the end of the Galactic Long Bar. By utilising the catalogued cloud distances plus new kinematic distance determinations, we are able to separate the dense BGPS clumps into these three main line-of-sight components to look for variations in star-formation properties that might be related to the different Galactic environments. We find no evidence of any difference in either the clump mass function or the average clump formation efficiency (CFE) between these components that might be attributed to environmental effects on scales comparable to Galactic-structure features.

Despite having a very high star-formation rate, and containing at least one cloud with a very high CFE, the star formation associated with the Scutum-Centaurus tangent does not appear to be in any way abnormal or different to that in the other two spiral-arm sections. Large variations in the CFE are found on the scale of individual clouds, however, which may be due to local triggering agents as opposed to the large-scale Galactic structure.

Accepted by Monthly Notices of the Royal Astronomical Society

<http://arxiv.org/abs/1203.0295>

## Methanol and excited OH masers towards W51: I - Main and South

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MERLIN phase-referenced polarimetric observations towards the W51 complex were carried out in March 2006 in the Class II methanol maser transition at 6.668 GHz and three of the four excited OH maser hyperfine transitions at 6 GHz. Methanol maser emission is found towards both W51 Main and South. We did not detect any emission in the excited OH maser lines at 6.030 and 6.049 GHz down to a  $3\sigma$  limit of  $\sim 20$  mJy beam<sup>-1</sup>. Excited OH maser emission at 6.035-GHz is only found towards W51 Main. This emission is highly circularly polarised (typically  $\geq 45\%$  and up to 87%). Seven Zeeman pairs were identified in this transition, one of which contains detectable linear polarisation. The magnetic field strength derived from these Zeeman pairs ranges from +1.6 to +6.8 mG, consistent with the previously published magnetic field strengths inferred from the OH ground-state lines. The bulk of the methanol maser emission is associated with W51 Main, sampling a total area of  $\sim 3'' \times 2.2''$  (i.e.,  $\sim 16200 \times 11900$  AU), while only two maser components, separated by  $\sim 2.5''$ , are found in the W51 South region. The astrometric distributions of both 6.668-GHz methanol and 6.035-GHz excited-OH maser emission in the W51 Main/South region are presented here. The methanol masers in W51 Main show a clear coherent velocity and spatial structure with the bulk of the maser components distributed into 2 regions showing a similar conical opening angle with of a central velocity of  $\sim +55.5$  km s<sup>-1</sup> and an expansion velocity of  $\leq 5$  km s<sup>-1</sup>. The mass contained in this structure is estimated to be at least  $22 M_\odot$ . The location of maser emission in the two afore-mentioned lines is compared with that of previously published OH ground-state emission. Association with the UCHII regions in the W51 Main/South complex and relationship of the masers to infall or outflow in the region are discussed.

Accepted by MNRAS

<http://arxiv.org/abs/1203.2527>

# Probing the anomalous extinction of four young star clusters: the use of colour-excess, main-sequence fitting and fractal analysis.

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*Aims.* We studied four young star clusters to characterize their anomalous extinction or variable reddening and assess whether they could be due to contamination either by dense clouds or circumstellar effects.

*Methods.* We evaluated the extinction law ( $R_V$ ) by adopting two methods: (i) the use of theoretical expressions based on the colour-excess of stars with known spectral type, and (ii) the analysis of two-colour diagrams, where the slope of the observed colour distribution was compared to the normal distribution. An algorithm to reproduce the zero-age main-sequence (ZAMS) reddened colours was developed to derive the average visual extinction ( $A_V$ ) that provides the closest fit to the observational data. The structure of the clouds was evaluated by means of a statistical fractal analysis, designed to compare their geometric structure with the spatial distribution of the cluster members.

*Results.* The cluster NGC 6530 is the only object of our sample affected by anomalous extinction. On average, the other clusters suffer normal extinction, but several of their members, mainly in NGC 2264, seem to have high  $R_V$ , probably because of circumstellar effects. The ZAMS fitting provides  $A_V$  values that are in good agreement with those found in the literature. The fractal analysis shows that NGC 6530 has a centrally concentrated distribution of stars that differs from those of the sub-structures found in the density distribution of the cloud projected in the  $A_V$  map, suggesting that the original cloud was changed by the cluster formation. However, the fractal dimension and statistical parameters of Berkeley 86, NGC 2244, and NGC 2264 indicate that there is a good cloud-cluster correlation, when compared to other works based on an artificial distribution of points.

Accepted by Astronomy & Astrophysics

<http://arxiv.org/abs/1202.6280>

## Silica-Rich Bright Debris Disk around HD 15407A

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We report an intriguing debris disk towards the F3V star HD 15407A, in which an extremely large amount of warm fine dust ( $\sim 10^{-7} M_{\oplus}$ ) is detected. The dust temperature is derived as  $\sim 500$ – $600$  K and the location of the debris dust is estimated as 0.6–1.0 AU from the central star, a terrestrial planet region. The fractional luminosity of the debris disk is  $\sim 0.005$ , which is much larger than those predicted by steady-state models of the debris disk produced by planetesimal collisions. The mid-infrared spectrum obtained by *Spitzer* indicates the presence of abundant  $\mu\text{m}$ -sized silica dust, suggesting that the dust comes from the surface layer of differentiated large rocky bodies and might be trapped around the star.

Accepted by The Astrophysical Journal Letters

<http://jp.arxiv.org/abs/1203.2534>

# Confirming the Primarily Smooth Structure of the Vega Debris Disk at Millimeter Wavelengths

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Clumpy structure in the debris disk around Vega has been previously reported at millimeter wavelengths and attributed to concentrations of dust grains trapped in resonances with an unseen planet. However, recent imaging at similar wavelengths with higher sensitivity has disputed the observed structure. We present three new millimeter-wavelength observations that help to resolve the puzzling and contradictory observations. We have observed the Vega system with the Submillimeter Array (SMA) at a wavelength of 880  $\mu\text{m}$  and angular resolution of 5''; with the Combined Array for Research in Millimeter-wave Astronomy (CARMA) at a wavelength of 1.3 mm and angular resolution of 5''; and with the Green Bank Telescope (GBT) at a wavelength of 3.3 mm and angular resolution of 10''. Despite high sensitivity and short baselines, we do not detect the Vega debris disk in either of the interferometric data sets (SMA and CARMA), which should be sensitive at high significance to clumpy structure based on previously reported observations. We obtain a marginal ( $3\sigma$ ) detection of disk emission in the GBT data; the spatial distribution of the emission is not well constrained. We analyze the observations in the context of several different models, demonstrating that the observations are consistent with a smooth, broad, axisymmetric disk with inner radius 20-100 AU and width  $\gtrsim 50$  AU. The interferometric data require that at least half of the 860  $\mu\text{m}$  emission detected by previous single-dish observations with the James Clerk Maxwell Telescope be distributed axisymmetrically, ruling out strong contributions from flux concentrations on spatial scales of  $\lesssim 100$  AU. These observations support recent results from the Plateau de Bure Interferometer indicating that previous detections of clumpy structure in the Vega debris disk were spurious.

Accepted by Astrophysical Journal

[http://astro.berkeley.edu/~mhughes/download/hughes\\_vega.pdf](http://astro.berkeley.edu/~mhughes/download/hughes_vega.pdf)

## The present-day mass function of the Quintuplet cluster based on proper motion membership

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*Context:* The stellar mass function is a probe for a potential dependence of star formation on the environment. Only a few young clusters are known to reside within the central molecular zone and can serve as testbeds for star formation under the extreme conditions in this region.

*Aims:* We determine the present-day mass function of the Quintuplet cluster, a young massive cluster in the vicinity of the Galactic centre.

*Methods:* We use two epochs of high resolution near infrared imaging data obtained with NAOS/CONICA at the ESO

VLT to measure the individual proper motions of stars in the Quintuplet cluster in the cluster reference frame. An unbiased sample of cluster members within a radius of 0.5 pc from the cluster centre was established based on their common motion with respect to the field and a subsequent colour-cut. Initial stellar masses were inferred from four isochrones covering ages from 3 to 5 Myr and two sets of stellar evolution models. For each isochrone, the present-day mass function of stars was determined for the full sample of main sequence cluster members using an equal number binning scheme.

*Results:* We find the slope of the present-day mass function in the central part of the Quintuplet cluster to be  $\alpha = -1.68_{-0.09}^{+0.13}$  for an approximate mass range from 5 to 40  $M_{\odot}$ , which is significantly flatter than the Salpeter slope of  $\alpha = -2.35$ . The flattening of the present-day mass function may be caused by rapid dynamical evolution of the cluster in the strong Galactic centre tidal field. The derived mass function slope is compared to the values found in other young massive clusters in the Galaxy.

Accepted by Astronomy & Astrophysics

## Near-Infrared H<sub>2</sub> and Continuum Survey of Extended Green Objects

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The *Spitzer* GLIMPSE survey has revealed a number of "Extended Green Objects" (EGOs) which display extended emission at 4.5  $\mu\text{m}$ . These EGOs are potential candidates for high mass protostellar outflows. We have used high resolution ( $< 1''$ ) H<sub>2</sub> 1-0 S(1) line, *K*, and *H*-band images from the United Kingdom Infrared Telescope to study 34 EGOs to investigate their nature. We found that 12 EGOs exhibit H<sub>2</sub> outflows (two with chains of H<sub>2</sub> knotty structures; five with extended H<sub>2</sub> bipolar structures; three with extended H<sub>2</sub> lobes; two with pairs of H<sub>2</sub> knots). In the 12 EGOs with H<sub>2</sub> outflows, three of them exhibit similar morphologies between the 4.5  $\mu\text{m}$  and H<sub>2</sub> emission. However, the remaining 9 EGOs show that the H<sub>2</sub> features are more extended than the continuum features, and the H<sub>2</sub> emission is seldom associated with continuum emission. Furthermore, the morphologies of the near-infrared continuum and 4.5  $\mu\text{m}$  emission are similar to each other for those EGOs with *K*-band emission, implying that at least a part of the IRAC-band continuum emission of EGOs comes from scattered light from the embedded YSOs.

Accepted by ApJS

<http://arxiv.org/abs/1203.2416>

## Impact of protostellar outflow on star formation: effects of the initial cloud mass

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The effects of protostellar outflow on the star formation in a single cloud core are investigated by three-dimensional resistive MHD simulations. Starting from the prestellar cloud core, the star formation process is calculated until the end of the main accretion phase. In the calculations, the mass of the prestellar cloud is parameterized. During the star formation, the protostellar outflow is driven by the circumstellar disk. The outflow extends also in the transverse direction until its width becomes comparable to the initial cloud scale, and thus, the outflow has a wide opening angle of  $\gtrsim 40^\circ$ . As a result, the protostellar outflow sweeps up a large fraction of the infalling material and ejects it into the interstellar space. The outflow can eject at most over half of the host cloud mass, significantly decreasing star formation efficiency. The outflow power is stronger in clouds with a greater initial mass. Thus, the protostellar outflow effectively suppresses star formation efficiency in a massive cloud. The outflow weakens significantly and disappears in several free-fall timescales of the initial cloud after the cloud begins to collapse. The natal prestellar core influences

the lifetime and size of the outflow. At the end of the main accretion phase, a massive circumstellar disk comparable in mass to the protostar remains. Calculations show that  $\sim 26 - 54\%$  of the initial cloud mass is converted into the protostar and  $\sim 8 - 40\%$  remains in the circumstellar disk, while  $\sim 8 - 49\%$  can be ejected into the interstellar space by the protostellar outflow. Therefore, the protostellar outflow can decrease the star formation efficiency to  $\sim 50\%$  at the maximum.

Accepted by MNRAS

<http://arxiv.org/abs/1108.3564>

## Detection of OD towards the low-mass protostar IRAS16293-2422

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Although water is an essential and widespread molecule in star-forming regions, its chemical formation pathways are still not very well constrained. Observing the level of deuterium fractionation of OH, a radical involved in the water chemical network, is a promising way to infer its chemical origin. We aim at understanding the formation mechanisms of water by investigating the origin of its deuterium fractionation. This can be achieved by observing the abundance of OD towards the low-mass protostar IRAS16293–2422, where the HDO distribution is already known. Using the GREAT receiver on board SOFIA, we observed the ground-state OD transition at 1391.5 GHz towards the low-mass protostar IRAS16293–2422. We also present the detection of the HDO  $1_{11}-0_{00}$  line using the APEX telescope. We compare the OD/HDO abundance ratio inferred from these observations with the predictions of chemical models. The OD line is detected in absorption towards the source continuum. This is the first detection of OD outside the solar system. The SOFIA observation, coupled to the observation of the HDO  $1_{11}-0_{00}$  line, provides an estimate of the abundance ratio OD/HDO  $\sim 17-90$  in the gas where the absorption takes place. This value is fairly high compared with model predictions. This may be reconciled if reprocessing in the gas by means of the dissociative recombination of  $\text{H}_2\text{DO}^+$  further fractionates OH with respect to water. The present observation demonstrates the capability of the SOFIA/GREAT instrument to detect the ground transition of OD towards star-forming regions in a frequency range that was not accessible before. Dissociative recombination of  $\text{H}_2\text{DO}^+$  may play an important role in setting a high OD abundance. Measuring the branching ratios of this reaction in the laboratory will be of great value for chemical models.

Accepted by Astronomy & Astrophysics, SOFIA/GREAT special issue

<http://arxiv.org/abs/1203.2825>

## On the origin of planets at very wide orbits from the re-capture of free floating planets

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In recent years several planets have been discovered at wide orbits ( $> 100$  AU) around their host stars. Theoretical studies encounter difficulties in explaining their formation and origin. Here we propose a novel scenario for the production of planetary systems at such orbits, through the dynamical recapture of free floating planets (FFPs) in dispersing stellar clusters and stellar associations. This process is a natural extension of the recently suggested scenario for the formation of wide stellar binaries. We use N-body simulations of dispersing clusters with  $10 - 1000$  stars and comparable numbers of FFPs to study this process. We find that planets are captured into wide orbits in the typical range  $\sim \text{few} \times 100 - 10^6$  AU, and have a wide range of eccentricities (thermal distribution). Typically,  $3 - 6 \times (f_{\text{FFP}}/1)$  % of all stars capture a planetary companion with such properties (where  $f_{\text{FFP}}$  is the number of FFP per star in the

birth clusters). The planetary capture efficiency is comparable to that of capture-formed stellar-binaries, and shows a similar dependence on the cluster size and structure. It is almost independent of the specific planetary mass; planets as well as sub-stellar companions of any mass can be captured. The capture efficiency decreases with increasing cluster size, and for a given cluster size it increases with the host/primary mass. We also find that more than one planet can be captured around the same host through independent consecutive captures; similarly planets can be captured into binary systems, both in circumstellar and circumbinary orbits. We also expect planets to be captured into pre-existing planetary (and protoplanetary systems) as well as into orbits around black holes and massive white dwarfs, if these formed early enough before the cluster dispersal. In particular, stellar black holes have a high capture efficiency ( $> 50\%$  and  $5 - 10 \times (f_{\text{FFP}}/1) \%$  for capture of stars and planetary companions, respectively) due to their large mass. Finally, although rare, two FFPs or brown dwarfs can become bound and form a FFP-binary system with no stellar host.

Accepted by Astrophysical Journal

<http://arxiv.org/abs/1202.2362>

## ***Herschel* far-infrared observations of the Carina Nebula complex: I: Introduction and global cloud structure**

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*Context:* The Carina Nebula represents one of the most massive star forming regions known in our Galaxy and displays a high level of feedback from the large number of very massive stars. While the stellar content is now well known from recent deep X-ray and near-infrared surveys, the properties of the clouds remained rather poorly studied until today.

*Aims:* By mapping the Carina Nebula complex in the far-infrared, we aim at a comprehensive and detailed characterization of the dust and gas clouds in the complex.

*Methods:* We used SPIRE and PACS onboard of *Herschel* to map the full spatial extent ( $\approx 5.3$  square-degrees) of the clouds in the Carina Nebula complex at wavelengths between  $70 \mu\text{m}$  and  $500 \mu\text{m}$ . We use here the  $70 \mu\text{m}$  and  $160 \mu\text{m}$  far-infrared maps to determine color temperatures and column densities, and to investigate the global properties of the gas and dust clouds in the complex.

*Results:* Our *Herschel* maps show the far-infrared morphology of the clouds at unprecedented high angular resolution. The clouds show a very complex and filamentary structure that is dominated by the radiation and wind feedback from the massive stars. In most locations, the column density of the clouds is  $N_{\text{H}} \leq 2 \times 10^{22} \text{cm}^{-2}$  (corresponding to visual extinctions of  $A_V \leq 10$  mag); denser cloud structures are restricted to the massive cloud west of Tr 14 and the innermost parts of large pillars. Our temperature map shows a clear large scale gradient from  $\approx 35 - 40$  K in the central region to  $\leq 20$  K at the periphery and in the densest parts of individual pillars. The total mass of the clouds seen by *Herschel* in the central (1 degree radius) region is  $\approx 656\,000 M_{\odot}$ . We also derive the global spectral energy distribution in the mid-infrared to mm wavelength range. A simple radiative transfer model suggests that the total mass of all the gas (including a warmer component that is not well traced by *Herschel*) in the central 1 degree radius region is  $\leq 890\,000 M_{\odot}$ .

*Conclusions:* Despite the strong feedback from numerous massive stars and the corresponding cloud dispersal processes that are going on since several million years, there are still several  $10\,000 M_{\odot}$  of cool cloud material present at column-densities sufficient for further star formation. Comparison of our total gas mass estimates to molecular cloud masses derived from CO line mapping suggests that as much as about 75% of all the gas is in atomic rather than molecular form.

Accepted for Astronomy & Astrophysics

Preprints can be obtained from <http://www.usm.uni-muenchen.de/people/preibisch/publications.html>

## **Direct imaging constraints on planet populations detected by microlensing**

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Results from gravitational microlensing suggested the existence of a large population of free-floating planetary mass objects. The main conclusion from this work was partly based on constraints from a direct imaging survey. This survey determined upper limits for the frequency of stars that harbor giant exoplanets at large orbital separations. We want to verify to what extent upper limits from direct imaging do indeed constrain the microlensing results. We examine the current derivation of the upper limits used in the microlensing study and re-analyze the data from the corresponding imaging survey. We focus on the mass and semi-major axis ranges that are most relevant in context of the microlensing results. We also consider new results from a recent M-dwarf imaging survey as these objects are typically the host stars for planets detected by microlensing. We find that the upper limits currently applied in context of the microlensing results are probably underestimated. This means that a larger fraction of stars than assumed may harbor gas giant planets at larger orbital separations. Also, the way the upper limit is currently used to estimate the fraction of free-floating objects is not strictly correct. If the planetary surface density of giant planets around M-dwarfs is described as  $df_{\text{Planet}} \propto a^\beta da$ , we find that  $\beta \leq 0.5 - 0.6$  is consistent with results from different observational studies probing semi-major axes between  $\sim 0.03 - 30$  AU. Having a higher upper limit on the fraction of stars that may have gas giant planets at orbital separations probed by the microlensing data implies that more of the planets detected in the microlensing study are potentially bound to stars rather than free-floating. The current observational data are consistent with a rising planetary surface density for giant exoplanets around M-dwarfs out to  $\sim 30$  AU. Future direct imaging surveys will show out to what semi-major axis the above mentioned range of  $\beta$  is valid and what fraction of the planetary mass objects detected by microlensing are indeed bound.

Accepted by Astronomy & Astrophysics as Research Note

<http://xxx.lanl.gov/abs/1203.3647>

## Detection of C<sub>60</sub> in embedded young stellar objects, a Herbig Ae/Be star and an unusual post-AGB star

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The first detection of the C<sub>60</sub> (Buckminsterfullerene) molecule in massive embedded young stellar objects (YSOs) is reported. Observations with *Spitzer* IRS reveal the presence of C<sub>60</sub> in YSOs ISOGAL-P J174639.6-284126 and SSTGC 372630 in the Central Molecular Zone in the Galactic centre, and in a YSO candidate, 2MASS J06314796+0419381, in the Rosette nebula. The first detection of C<sub>60</sub> in a Herbig Ae/Be star, HD 97300, is also reported. These observations extend the range of astrophysical environments in which C<sub>60</sub> is found to YSOs and a pre-main sequence star. C<sub>60</sub> excitation and formation mechanisms are discussed in the context of these results, together with its presence and processes in post-AGB objects such as HR 4049.

Accepted by MNRAS

## Magnetic Field in the Isolated Massive Dense Clump IRAS 20126+4104

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We measured polarized dust emission at 350  $\mu\text{m}$  towards the high-mass star forming massive dense clump IRAS 20126+4104 using the SHARC II Polarimeter, SHARP, at the Caltech Submillimeter Observatory. Most of the observed magnetic field vectors agree well with magnetic field vectors obtained from a numerical simulation for the case when the global magnetic field lines are inclined with respect to the rotation axis of the dense clump. The results of the numerical simulation show that rotation plays an important role on the evolution of the massive dense clump and its magnetic field. The direction of the cold CO 1-0 bipolar outflow is parallel to the observed magnetic field within the dense clump as well as the global magnetic field, as inferred from optical polarimetry data, indicating that the magnetic field also plays a critical role in an early stage of massive star formation. The large-scale Keplerian disk of the massive (proto)star rotates in almost opposite sense to the clump's envelope. The observed magnetic field morphology and the counter-rotating feature of the massive dense clump system provide hints to constrain the role of magnetic fields in the process of high mass star formation.

Accepted by the Astrophysical Journal Letters

<http://www.submm.caltech.edu/~hs/20126ii/ms.pdf>

## First Science Observations with SOFIA/FORCAST: 6 to 37 micron Imaging of the Central Orion Nebula

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We present new mid-infrared images of the central region of the Orion Nebula using the newly commissioned SOFIA airborne telescope and its 5 – 40  $\mu\text{m}$  camera FORCAST. The 37.1  $\mu\text{m}$  images represent the highest resolution observations ( $\lesssim 4''$ ) ever obtained of this region at these wavelengths. After BN/KL (which is described in a separate letter in this issue), the dominant source at all wavelengths except 37.1  $\mu\text{m}$  is the Ney-Allen Nebula, a crescent-shaped extended source associated with  $\theta^1$  D Ori. The morphology of the Ney-Allen nebula in our images is consistent with the interpretation that it is ambient dust swept up by the stellar wind from  $\theta^1$  D Ori, as suggested by Smith et al. (2005). Our observations also reveal emission from two “proplyds” (proto-planetary disks), and a few embedded young stellar objects (YSOs; IRC 9, and OMC1S IRS1, 2, and 10). The spectral energy distribution for IRC 9 is presented and fitted with standard YSO models from Robitaille et al. (2007) to constrain the total luminosity, disk size, and envelope size. The diffuse, nebular emission we observe at all FORCAST wavelengths is most likely from the background photodissociation region (PDR) and shows structure that coincides roughly with H $\alpha$  and [N II] emission. We conclude that the spatial variations in the diffuse emission are likely due to undulations in the surface of the background PDR.

Accepted by ApJ Letters, Special SOFIA Issue.

<http://arxiv.org/abs/1202.4479>

## Shadows, gaps, and ring-like structures in protoplanetary disks

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We study the structure of passively heated disks around T Tauri and Herbig Ae stars, and present a vectorized Monte Carlo dust radiative transfer model of protoplanetary disks. The vectorization provides a speed up factor of 100 when compared to a scalar version of the code. Disks are composed of either fluffy carbon and silicate grains of various sizes or dust of the diffuse ISM. The IR emission and the midplane temperature derived by the MC method differ from models where the radiative transfer is solved in slab geometry of small ring segments. In the MC treatment, dusty halos above the disks are considered. Halos lead to an enhanced IR emission and warmer midplane temperature than do pure disks. Under the assumption of hydrostatic equilibrium we find that the disk in the inner rim puffs up, followed by a shadowed region. The shadow reduces the temperature of the midplane and decreases the height of the extinction layer of the disk. It can be seen as a gap in the disk unless the surface is again exposed to direct stellar radiation. There the disk puffs up a second time, a third time and so forth. Therefore several gaps and ring-like structures are present in the disk surface and appear in emission images. They result from shadows in the disks and are present without the need to postulate the existence of any companion or planet. As compared to Herbig Ae stars, such gaps and ring-like structures are more pronounced in regions of terrestrial planets around T Tauri stars.

Accepted by A&A

## Mining the UKIDSS GPS: star formation and embedded clusters

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*Context.* Data mining techniques must be developed and applied to analyse the large public data bases containing hundreds to thousands of millions entries.

*Aims.* To develop methods for locating previously unknown stellar clusters from the UKIDSS Galactic Plane Survey catalogue data.

*Methods.* The cluster candidates are computationally searched from pre-filtered catalogue data using a method that fits a mixture model of Gaussian densities and background noise using the Expectation Maximization algorithm. The catalogue data contains a significant number of false sources clustered around bright stars. A large fraction of these artefacts were automatically filtered out before or during the cluster search. The UKIDSS data reduction pipeline tends to classify marginally resolved stellar pairs and objects seen against variable surface brightness as extended objects (or "galaxies" in the archive parlance). 10% or  $66 \times 10^6$  of the sources in the UKIDSS GPS catalogue brighter than  $17^m$  in the *K* band are classified as "galaxies". Young embedded clusters create variable NIR surface brightness because the gas/dust clouds in which they were formed scatters the light from the cluster members. Such clusters appear therefore as clusters of "galaxies" in the catalogue and can be found using only a subset of the catalogue data. The detected "galaxy clusters" were finally screened visually to eliminate the remaining false detections due to data artefacts. Besides the embedded clusters the search also located locations of non clustered embedded star formation.

*Results.* The search covered an area of  $1302 \text{ deg}^2$  and 137 previously unknown cluster candidates and 30 previously unknown sites of star formation were found.

Accepted by A&A

## Multiple outflows from the luminous YSO IRAS 07422-2001

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The luminous Young Stellar Object (YSO) IRAS 07422-2001 is studied in the infrared. We discover star forming activity in embedded clusters located in a cloud detected at mid-IR wavelengths in emission. Multiple outflows are discovered from these clusters in the H<sub>2</sub> ro-vibrational line at 2.122 micron. We detect at least six outflows from the cluster associated with the IRAS source and another outflow from a source located in a cluster detected 2.7 arcmin NE of the IRAS source. Additional star formation is taking place in two other cluster candidates within the cloud. Three of the YSOs in the cluster associated with the IRAS source are detected at 11.2 micron at an angular resolution of 0.8 arcsec. We have a tentative detection of a circumstellar disk in this cluster, seen as an extinction lane in the J and H-band images. The spectral energy distributions (SEDs) of the dominant YSOs in the cluster associated with the IRAS source and in the NE cluster are studied using radiative transfer models and the properties of the YSOs are estimated. The YSO associated with the IRAS source is probably in a very early Class I stage of formation. The source identified as the dominant YSO in the NE cluster appears to be older than the dominant YSO in the cluster associated with the IRAS source, but its observed flux seems to be contaminated by extra emission, which suggests the presence of a young source contributing to the SED at far-IR wavelengths. The star formation observed in the field of IRAS 07422-2001 supports the idea of hierarchical formation of massive star clusters and the growth of massive young stellar objects near the centres of multiple sub-clusters in a star forming clump through competitive accretion.

Accepted by Astronomy and Astrophysics

<http://arxiv.org/abs/1202.4795>

## Interstellar polarization and grain alignment: the role of iron and silicon

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We compiled the polarimetric data for a sample of lines of sight with known abundances of Mg, Si, and Fe. We correlated the degree of interstellar polarization  $P$  and polarization efficiency (the ratio of  $P$  to the colour excess  $E(B - V)$  or extinction  $A_V$ ) with dust phase abundances. We detect an anticorrelation between  $P$  and the dust phase abundance of iron in non silicate-containing grains  $[\text{Fe}(\text{rest})/\text{H}]_d$ , a correlation between  $P$  and the abundance of Si, and no correlation between  $P/E(B - V)$  or  $P/A_V$  and dust phase abundances. These findings can be explained if mainly the silicate grains aligned by the radiative mechanism are responsible for the observed interstellar linear polarization.

Accepted by Astronomy & Astrophysics

<http://arxiv.org/abs/1203.3677>

## High-resolution absorption spectroscopy of the OH $^2\Pi_{3/2}$ ground state line

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The chemical composition of the interstellar medium is determined by gas phase chemistry, assisted by grain surface reactions, and by shock chemistry. The aim of this study is to measure the abundance of the hydroxyl radical (OH) in diffuse spiral arm clouds as a contribution to our understanding of the underlying network of chemical reactions. Owing to their high critical density, the ground states of light hydrides provide a tool to directly estimate column densities by means of absorption spectroscopy against bright background sources. We observed onboard the SOFIA

observatory the  ${}^2\Pi_{3/2}$ ,  $J = 5/2 - 3/2$  2.5 THz line of ground-state OH in the diffuse clouds of the Carina-Sagittarius spiral arm. OH column densities in the spiral arm clouds along the sightlines to W49N, W51 and G34.26+0.15 were found to be of the order of  $10^{14}\text{cm}^{-2}$ , which corresponds to a fractional abundance of  $10^{-7}$  to  $10^{-8}$ , which is comparable to that of  $\text{H}_2\text{O}$ . The absorption spectra of both species have similar velocity components, and the ratio of the derived  $\text{H}_2\text{O}$  to OH column densities ranges from 0.3 to 1.0. In W49N we also detected the corresponding line of  ${}^{18}\text{OH}$ .

Accepted by Astronomy and Astrophysics

<http://dx.doi.org/10.1051/0004-6361/201218915>, <http://arxiv.org/abs/1203.1744>

## A Resolved Millimeter Emission Belt in the AU Mic Debris Disk

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We present imaging observations at 1.3 millimeters of the debris disk surrounding the nearby M-type flare star AU Mic with beam size  $3''$  (30 AU) from the Submillimeter Array. These data reveal a belt of thermal dust emission surrounding the star with the same edge-on geometry as the more extended scattered light disk detected at optical wavelengths. Simple modeling indicates a central radius of  $\sim 35$  AU for the emission belt. This location is consistent with the reservoir of planetesimals previously invoked to explain the shape of the scattered light surface brightness profile through size-dependent dust dynamics. The identification of this belt further strengthens the kinship between the debris disks around AU Mic and its more massive sister star  $\beta$  Pic, members of the same  $\sim 10$  Myr-old moving group.

Accepted by ApJ Letters

<http://arxiv.org/abs/1203.1896>

## Terahertz ammonia absorption as a probe of infall in high-mass star forming clumps

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Cloud contraction and infall are the fundamental processes of star formation. While "blue-skewed" line profiles observed in high-mass star forming regions are commonly taken as evidence of infall by an ever increasing number of studies, their interpretation offers many pitfalls. Detecting infall via redshifted absorption in front of continuum sources is a much more direct and reliable method but so far mostly restricted toward absorption in the centimeter toward strong HII regions. Here we present a novel approach by probing absorption of rotational ammonia transitions in front of the strong dust emission of massive star-forming regions. A carefully selected sample of three regions with different stages of evolution is selected to study infall through the evolution of massive star-forming clumps. Redshifted absorption is detected toward all three sources and infall rates between  $3\text{-}10 \times 10^{-3}$   $\text{Msol yr}^{-1}$  are derived.

Accepted by A&A (SOFIA/GREAT special issue)

<http://arxiv.org/abs/1203.3406>

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

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Due to the gravitational influence of density fluctuations driven by magneto-rotational instability in the gas disk, planetesimals and protoplanets undergo diffusive radial migration as well as changes in other orbital properties. The magnitude of the effect on particle orbits can have important consequences for planet formation scenarios. We use the local-shearing-box approximation to simulate an ideal, isothermal, magnetized gas disk with vertical density stratification and simultaneously evolve numerous massless particles moving under the gravitational field of the gas and the host star. We measure the evolution of the particle orbital properties, including mean radius, eccentricity, inclination, and velocity dispersion, and its dependence on the disk properties and the particle initial conditions. Although the results converge with resolution for fixed box dimensions, we find the response of the particles to the gravity of the turbulent gas correlates with the horizontal box size, up to 16 disk scale heights. This correlation indicates that caution should be exercised when interpreting local-shearing-box models involving gravitational physics of magneto-rotational turbulence. Based on heuristic arguments, nevertheless, the criterion  $L_h/R \sim O(1)$ , where  $L_h$  is the horizontal box size and  $R$  is the distance to the host star, is proposed to possibly circumvent this conundrum. If this criterion holds, we can still conclude that magneto-rotational turbulence seems likely to be ineffective at driving either diffusive migration or collisional erosion under most circumstances.

Accepted by The Astrophysical Journal

<http://arxiv.org/abs/1103.3268>

### **APEX-CHAMP<sup>+</sup> high- $J$ CO observations of low-mass young stellar objects: III. NGC 1333 IRAS 4A/4B envelope, outflow and UV heating**

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*Context:* The NGC 1333 IRAS 4A and IRAS 4B sources are among the best studied Stage 0 low-mass protostars which are driving prominent bipolar outflows. Spectrally resolved molecular emission lines provide crucial information regarding the physical and chemical structure of the circumstellar material as well as the dynamics of the different components. Most studies have so far concentrated on the colder parts ( $T \leq 30$  K) of these regions.

*Aims:* The aim is to characterize the warmer parts of the protostellar envelope using the new generation of submillimeter instruments. This will allow us to quantify the feedback of the protostars on their surroundings in terms of shocks, UV heating, photodissociation and outflow dispersal.

*Methods:* The dual frequency  $2 \times 7$  pixel 650/850 GHz array receiver CHAMP<sup>+</sup> mounted on APEX was used to obtain a fully sampled, large-scale  $\sim 4' \times 4'$  map at  $9''$  resolution of the IRAS 4A/4B region in the  $^{12}\text{CO } J=6-5$  line. Smaller maps are observed in the  $^{13}\text{CO } 6-5$  and  $[\text{C I}] J=2-1$  lines. In addition, a fully sampled  $^{12}\text{CO } J=3-2$  map made with HARP-B on the JCMT is presented and deep isotopolog observations are obtained at selected outflow positions to constrain the optical depth. Complementary *Herschel*-HIFI and ground-based lines of CO and its isotopologs, from  $J=1-0$  up to  $10-9$  ( $E_u/k \approx 300$  K), are collected at the source positions and used to construct velocity resolved CO ladders and rotational diagrams. Radiative-transfer models of the dust and lines are used to determine temperatures and masses of the outflowing and photon-heated gas and infer the CO abundance structure.

*Results:* Broad CO emission line profiles trace entrained shocked gas along the outflow walls, with typical temperatures of  $\sim 100$  K. At other positions surrounding the outflow and the protostar, the 6-5 line profiles are narrow indicating UV excitation. The narrow  $^{13}\text{CO } 6-5$  data directly reveal the UV heated gas distribution for the first time. The amount of UV-photon-heated gas and outflowing gas are quantified from the combined  $^{12}\text{CO}$  and  $^{13}\text{CO } 6-5$  maps and found to be comparable within a  $20''$  radius around IRAS 4A, which implies that UV photons can affect the gas as much as the outflows. Weak  $[\text{C I}]$  emission throughout the region indicates a lack of CO dissociating photons. Modeling of the  $\text{C}^{18}\text{O}$  lines indicates the necessity of a “drop” abundance profile throughout the envelopes where the CO freezes out and is reloaded back into the gas phase through grain heating, thus providing quantitative evidence for the CO ice evaporation zone around the protostars. The inner abundances are less than the canonical value of

CO/H<sub>2</sub>=2.7×10<sup>-4</sup>, however, indicating some processing of CO into other species on the grains. The implications of our results for the analysis of spectrally unresolved *Herschel* data are discussed.

Accepted by Astronomy & Astrophysics, 2012

<http://arxiv.org/abs/1203.2965>

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

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

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

## Moving ... ??

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

## **Low-mass pre-main-sequence stars in the Magellanic Clouds**

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The stellar Initial Mass Function (IMF) suggests that stars with sub-solar mass form in very large numbers. Most attractive places for catching low-mass star formation in the act are young stellar clusters and associations, still (half-)embedded in star-forming regions. The low-mass stars in such regions are still in their pre-main-sequence (PMS) evolutionary phase, i.e., they have not started their lives on the main-sequence yet. The peculiar nature of these objects and the contamination of their samples by the fore- and background evolved populations of the Galactic disk impose demanding observational techniques, such as X-ray surveying and optical spectroscopy of large samples for the detection of complete numbers of PMS stars in the Milky Way. The Magellanic Clouds, the metal-poor companion galaxies to our own, demonstrate an exceptional star formation activity. The low extinction and stellar field contamination in star-forming regions of these galaxies imply a more efficient detection of low-mass PMS stars than in the Milky Way, but their distance from us make the application of the above techniques unfeasible. Nonetheless, imaging with the *Hubble Space Telescope* within the last five years yield the discovery of solar and sub-solar PMS stars in the Magellanic Clouds from photometry alone. Unprecedented numbers of such objects are identified as the low-mass stellar content of star-forming regions in these galaxies, changing completely our picture of young stellar systems outside the Milky Way, and extending the extragalactic stellar IMF below the persisting threshold of a few solar masses. This review presents the recent developments in the investigation of the PMS stellar content of the Magellanic Clouds, with special focus on the limitations by single-epoch photometry that can only be circumvented by the detailed study of the observable behavior of these stars in the color-magnitude diagram. The achieved characterization of the low-mass PMS stars in the Magellanic Clouds allowed thus a more comprehensive understanding of the star formation process in our neighboring galaxies.

Accepted by Space Science Reviews

<http://arxiv.org/abs/1202.6534>

## **The reliability of age measurements for Young Stellar Objects from Hertzsprung-Russell or color-magnitude diagrams**

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The possibility to estimate ages and masses of Young Stellar Objects (YSOs) from their location in the Hertzsprung-Russell diagram (HRD) or a color-magnitude diagram provides a very important tool for the investigation of fundamental questions related to the processes of star formation and early stellar evolution. Age estimates are essential for studies of the temporal evolution of circumstellar material around YSOs and the conditions for planet formation. The characterization of the age distribution of the YSOs in a star forming region allows researchers to reconstruct the star formation history and provides important information on the fundamental question of whether star formation is a slow or a fast process. However, the reliability of these age measurements and the ability to detect possible age spreads in the stellar population of star forming regions are fundamentally limited by several factors. The variability of YSOs, unresolved binary components, and uncertainties in the calibrations of the stellar parameters cause uncertainties in the derived luminosities that are usually much larger than the typical photometry errors. Furthermore, the pre-main sequence evolution track of a YSO depends to some degree on the initial conditions and the details of its individual accretion history. I discuss how these observational and model uncertainties affect the derived isochronal ages, and demonstrate how neglecting or underestimating these uncertainties can easily lead to severe misinterpretations, gross overestimates of the age spread, and ill-based conclusions about the star formation history. These effects are illustrated by means of Monte-Carlo simulations of observed star clusters with realistic observational uncertainties. The most important points are as follows. First, the observed scatter in the HRD must not be confused with a genuine age spread, but is always just an upper limit to the true age spread. Second, histograms of isochronal ages naturally show

a decreasing number of stars for ages above the median, a pattern that can be misinterpreted as an accelerating star formation rate. Third, it is emphasized that many star forming regions consist of several sub-groups, which often have different ages. If these distinct stellar populations cannot be disentangled (e.g., due to projection effects) and the HRD of all stars in the region is used for an age analysis, it is very difficult (often impossible) to discern between the scenario of an extended period of star formation (i.e. a large age spread) and the alternative concept of a temporal sequence of several discrete star formation episodes. Considering these factors, most observations of star forming regions suggest that age spreads are usually smaller than the corresponding crossing times, supporting the scenario of fast and dynamic star formation.

Research in Astronomy and Astrophysics 12, 1 ([iopscience.iop.org/1674-4527/12/1/001/](http://iopscience.iop.org/1674-4527/12/1/001/))

Preprint: [www.usm.uni-muenchen.de/people/preibisch/publications.html](http://www.usm.uni-muenchen.de/people/preibisch/publications.html)

## **The first results from the Herschel-HIFI mission**

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This paper contains a summary of the results from the first years of observations with the HIFI instrument onboard ESA's Herschel space observatory.

The paper starts with a summary of the goals and possibilities of far-infrared and submillimeter astronomy, the limitations of the Earth's atmosphere, and the scientific scope of the Herschel-HIFI mission.

The presentation of science results from the mission follows the life cycle of gas in galaxies as grouped into five themes: Structure of the interstellar medium, First steps in interstellar chemistry, Formation of stars and planets, Solar system results and Evolved stellar envelopes.

The HIFI observations paint a picture where the interstellar medium in galaxies has a mixed, rather than a layered structure; the same conclusion may hold for protoplanetary disks.

In addition, the HIFI data show that exchange of matter between comets and asteroids with planets and moons plays a large role.

The paper concludes with an outlook to future instrumentation in the far-infrared and submillimeter wavelength ranges.

Accepted by Advances of Space Research

<http://www.sron.rug.nl/~vdtak/adsres.pdf>

## **Postdoctoral Position in Computational Stellar Astrophysics in Exeter**

The astrophysics group at the University of Exeter invites applications for a postdoc position to work primarily with Isabelle Baraffe and other members of the group on theoretical and numerical aspects of stellar/planetary physics and evolution. The broad goal of the position is to work on 3D hydrodynamical modelling of stellar/planetary interiors, using a time implicit and fully compressible multi-D hydrodynamical code currently developed in Exeter with a group of international collaborators. The main purpose is to describe and understand various processes characteristic of star/planet interiors and evolution, like turbulence, convection, rotation, instabilities, oscillations. The postdoc will participate to further developments of our 3D numerical tool.

In the framework of this postdoc position, we are particularly interested in following the very early phases of evolution of low mass stars and brown dwarfs. The main purpose is to provide an advanced description through multi-D simulations of the effect of accretion on the structure of objects at their earliest stage of evolution. These simulations will bridge the gap between the embedded phases of star formation and the early phases of evolution of young brown dwarfs and low mass stars. This project is thus also linked to the field of star formation, a thriving field of research with involves cutting-edge, large ground- and space-based observational projects (HST, VLT, HERSCHEL, ALMA, SPITZER, JWST).

We are particularly interested in theoretical/numerical candidates with a strong background in computational astrophysics/fluid dynamics ; prior work on stellar and/or planetary interiors and evolution is not necessarily required. Applicants must possess a PhD in Astrophysics, Physics, or related discipline (e.g applied mathematics/fluid dynamics/computational methods).

The starting salary will be from 24,520 per annum on Grade E, depending on qualifications and experience.

This position is available for a period of two years commencing between July 2012 and December 31st 2012. Extensive supercomputing resources and funding for computing equipment and travel will be available to the post holder. For further information, please contact Isabelle Baraffe ([i.baraffe@ex.ac.uk](mailto:i.baraffe@ex.ac.uk)). To apply, send to Isabelle Baraffe a CV, publication lists, a detailed summary of research and a cover letter with the contact details of three referees and mentioning the post reference P43209.

The closing date for completed applications is April 30 2012.

## **Dublin Institute for Advanced Studies: Job Opportunities Working with the Mid-Infrared Instrument (MIRI) and in Star Formation**

Two contract posts are currently available as part of a European/US team to develop analysis software for the Mid-InfraRed Instrument (MIRI) while at the same time carrying out an active research program. MIRI will be flown on the James Webb Space Telescope (NASA and ESA's planned successor to the Hubble Space Telescope), which is due for launch in 2018. It is essential that applicants have a PhD in Astrophysics or a related subject. They should also have relevant experience with astronomical data processing and knowledge of C++ and a scripting language, such as Python, are advantageous. Successful applicants may expect to carry out their own astronomical research within the Star Formation Group led by Professor Tom Ray ([tr@cp.dias.ie](mailto:tr@cp.dias.ie)) who can be contacted for further information. Initial contracts will be for a 3-year period.

Applications, to include a CV, publication list, a short description of research interests, and the contact details of three referees should be sent, ideally as a single PDF file, to [eflood@cp.dias.ie](mailto:eflood@cp.dias.ie) quoting "MIRI Software Developers" in the subject field, to arrive on or before 30th April 2012. The positions will remain open until filled and are available from Summer 2012.

Included Benefits:

Salary will commence at 43,561 euro per year with annual increments subject to satisfactory performance. The posts are offered subject to the general Irish public service regulations and employment legislation (e.g. regarding maternity leave, holiday entitlements, etc.) and includes generous pension provision paid for by the employer.

## **A Photographic Atlas of Selected Regions of the Milky Way**

**Edward Emerson Barnard**

**Republished under the direction of Gerald Orin Dobek**

Eightyfive years ago, the finest work of Edward Emerson Barnard was published, four years after his death. *A Photographic Atlas of Selected Regions of the Milky Way*, containing 50 of Barnard's revolutionary photographs along the Milky Way, has ever since been a classic of astronomy, and a major influence in the development of the concept of the interstellar medium and molecular clouds, and eventually of formation of stars.

Only 700 copies were printed, for which Barnard personally had examined each of the 30,000+ photographs that were bound into the atlas. For years this book has been impossible to find. But now, thanks to the efforts of Gerald Orin Dobek, a new edition has been published by Cambridge University Press. The original two-volume set is now bound into a single large-format volume with the plates printed in magnificent quality. For each plate the original comments by Barnard are presented, followed by a table of objects of interest. Then the plate appears on a full page, with Barnard's drawing of the same region on the opposite page, marking the Barnard objects, many of which are now famous star forming regions, like B59 (the tip of the Pipe Nebula), B35 (hosting FU Orionis), B205 (associated with NGC 1333), B335 (the archetypical Bok globule containing a protostar), B42 (head of the  $\rho$  Ophiuchi cloud), and hundreds more. The precise identification of all these Barnard objects enabled by the reproduction of this book will facilitate the use of these classical cloud designations in modern work.

The book ends with a modern mosaic combining Barnard's 50 plates, showing their relative positions, and with a short biography of Barnard.

Not only is the reproduction of this book welcome as a historical document, but Barnard's largescale photographs are still today useful for understanding the larger context of individual star forming regions. Barnard, who was insistent on seeing his Atlas published with the best quality printing techniques available at the time, would have been thrilled to see this modern version of his main body of work.

Cambridge University Press 2011, ISBN 978-0-521-19143-2

358 pages, hardcover US\$125.00

Available from <http://www.cambridge.org/us/knowledge/isbn/item2705169>

## Meetings

# Revealing Evolution of Protoplanetary Disks in the ALMA Era

May 8-11, 2012, Kyoto, Japan

<http://www.kusastro.kyoto-u.ac.jp/kyoto.disk/>

Thanks to recent development of infrared and mm/submm instruments, detailed structure of dust, gas, and chemistry in protoplanetary disks has been revealed through observations of molecular lines and (polarized) dust emission. Now the ALMA Early Science has started and the forthcoming observations will reveal physical and chemical properties of planet-forming regions in the disks with its high spatial resolution and high sensitivity. Meanwhile, increasing numbers of exoplanets have been discovered these days and the Kepler spacecraft has opened a new window on the exoplanet observations. It is exactly the time to observationally test the planet formation theory which can explain formation of both our Solar system and exoplanets.

In this workshop we would like to discuss how we can approach planet formation theory through ALMA observations, which will renew our understandings of protoplanetary disks, together with detailed physical and chemical modelling. Key topics of the workshop will be observational tests of dust and gas evolution, including chemical evolution in the disks. For example,

- How can we connect observations of protoplanetary disks to the planet formation theory, which can explain properties (e.g., masses, densities, semi-major-axes, eccentricities) of exoplanets, in the context of gas and dust evolution?
- How can we reveal evolution of dust grains in the disks, such as coagulations, settling towards the midplane, and radial migration, as well as changes in their composition?
- How can we constrain gas dispersal mechanisms of disks, such as photoevaporation and gas accretion caused by magnetorotational instabilities?
- How do properties of central stars affect physics and chemistry of disks, and then planet formation?
- How can we discover evidences of planets and/or their migration in disks?
- How do properties of disks and embedded planets affect debris disk formation?
- How do chemical properties of disks lead to composition of (exo)planetary atmospheres and solid materials in our Solar system?

We look forward to fruitful discussions on evolution of protoplanetary disks towards planet formation with participants from wide range of fields.

### Invited Speakers

Edwige Chapillon (ASIAA, Taiwan)

Bill Dent (ESO ALMA, Chile)

Uma Gorti (SETI, USA)

Meredith Hughes (UC Berkeley, USA)

Shigeru Ida (Tokyo Tec., Japan)

Masahiro Ikoma (The University of Tokyo, Japan)

Gwendolyn Meeus (UAM, Spain)

Takayuki Muto (Tokyo Tec., Japan)

Satoshi Okuzumi (Nagoya University, Japan)

Klaus Pontoppidan (STSI, USA)

Charlie Qi (Harvard-Smithsonian CfA, USA)

Bun'ei Sato (Tokyo Tec., Japan)

Shogo Tachibana (The University of Tokyo, Japan)

Motohide Tamura (NAOJ, Japan)

Catherine Walsh (Queen's University Belfast, UK)

Jonathan Williams (University of Hawaii, USA)

### Scientific Organizing Committee

Shigeru Ida (Tokyo Tec., Japan), Yuri Aikawa (Kobe University), Hideko Nomura (Kyoto University)

**Abstract submission deadline : April 10, 2012**