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From the Editor

This month the Star Formation Newsletter celebrates its issue number 100. In the 8 1/2 years since the first experimental issue appeared, the Newsletter has grown in size with the increasing number of studies of star formation and associated topics. Also the number of subscribers has risen and steadily continues to do so: currently 860 researchers and students spread over 39 countries around the world receive the newsletter by e-mail every month. It appears safe to say that the Star Formation Newsletter has succeeded in its early ambition to become a vehicle for rapid dissemination of information of interest to the worldwide community of researchers in the field of star formation. The intervening years have also seen a broadening of the topics covered by the Newsletter, with star formation being linked more strongly in particular to early solar system studies and, more recently, to extrasolar planets, and abstracts on these topics are welcomed. Similarly, our understanding of the increasing number of β Pic-like systems has matured, with an increasing impact on our understanding of pre-main sequence circumstellar disks. Finally, although the Newsletter still does not include the vast topic of extragalactic star formation (for the poor but very real reason that I have limited time and no secretarial help in preparing the Newsletter), abstracts of star formation studies in the Magellanic Clouds are now included.

The Star Formation Newsletter is written *for* the community *by* the community. Without the active participation of the authors of new papers, the Newsletter would not exist, and it is gratifying to note that, despite the heavy demands on our time that we all suffer under, almost all relevant abstracts appear in the Newsletter. Still, a small fraction of papers are missed, and I therefore once more urge all readers to submit their abstracts.

With over 800 subscribers to the Newsletter, many of whom move from one position to another, the maintenance of the mailing list is becoming a somewhat laborious affair. It is a great and much appreciated help when updates to e-mail addresses are mailed to me before the old address becomes defunct.

Over the years a number of librarians have asked to receive the Newsletter for display in their libraries. This is an excellent way to broaden the readership, so if your librarian is willing every month to print a copy and display it among the newly received journals, please ask him/her to contact me to get on the mailing list.

Let me remind you that the section *Short Announcements* is available if you have brief information of general interest to the community, e.g. the availability of large data sets or software tools.

Finally, I would like to thank the many readers who have sent me positive feedback and encouragement over the years, and assure that I will continue to produce the Newsletter for as long as it serves a useful purpose.

Abstracts of recently accepted papers

Modes of Multiple Star Formation

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This paper argues that star forming environments should be classified into finer divisions than the traditional isolated and clustered modes. Using the observed set of galactic open clusters and theoretical considerations regarding cluster formation, we estimate the fraction of star formation that takes place within clusters. We find that less than $\sim 10\%$

of the stellar population originates from star forming regions destined to become open clusters, confirming earlier estimates. The smallest clusters included in the observational surveys (having at least $N \sim 100$ members) roughly coincide with the smallest stellar systems that are expected to evolve as clusters in a dynamical sense. We show that stellar systems with too few members $N < N_\star$ have dynamical relaxation times that are shorter than their formation times ($\sim 1 - 2$ Myr), where the critical number of stars $N_\star \approx 100$. Our results suggest that star formation can be characterized by (at least) three principal modes: [**I**] isolated singles and binaries, [**II**] groups ($N < N_\star$), and [**III**] clusters ($N > N_\star$). Many – if not most – stars form through the intermediate mode in stellar groups with $10 < N < 100$. Such groups evolve and disperse much more rapidly than do open clusters; groups also have a low probability of containing massive stars and are unaffected by supernovae and intense ultraviolet radiation fields. Because of their short lifetimes and small stellar membership, groups have relatively little effect on the star formation process (on average) compared to larger open clusters.

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Episodic accretion in magnetically layered protoplanetary discs

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We study protoplanetary disc evolution assuming that angular momentum transport is driven by gravitational instability at large radii, and magnetohydrodynamic (MHD) turbulence in the hot inner regions. At radii of the order of 1 AU such discs develop a magnetically layered structure, with accretion occurring in an ionized surface layer overlying quiescent gas that is too cool to sustain MHD turbulence. We show that layered discs are subject to a limit cycle instability, in which accretion onto the protostar occurs in $\sim 10^4$ yr bursts with $\dot{M} \sim 10^{-5} M_\odot \mathrm{yr}^{-1}$, separated by quiescent intervals lasting $\sim 10^5$ yr where $\dot{M} \approx 10^{-8} M_\odot \mathrm{yr}^{-1}$. Such bursts could lead to repeated episodes of strong mass outflow in Young Stellar Objects. The transition to this episodic mode of accretion occurs at an early epoch ($t \ll 1$ Myr), and the model therefore predicts that many young pre-main-sequence stars should have low rates of accretion through the inner disc. At ages of a few Myr, the discs are up to an order of magnitude more massive than the minimum mass solar nebula, with most of the mass locked up in the quiescent layer of the disc at $r \sim 1$ AU. The predicted rate of low mass planetary migration is reduced at the outer edge of the layered disc, which could lead to an enhanced probability of giant planet formation at radii of 1 – 3 AU.

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http://arXiv.org/abs/astro-ph/0101253

Evidence for Extinction and Accretion Variability in T Tau S

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We present angularly resolved spectra of T Tau North and South in the 3 μm water ice feature and K-band. Most of the water ice absorption lies along the line of sight toward T Tau South, confirming that it is viewed through stronger extinction. A decrease in ice-band absorption toward T Tau S between December 1998 and January 2000, significant at the 2σ level, was associated with an increase in its near infrared flux. Brγ emission is detected in T Tau North and South and H_2 (2.12 μm) emission only toward T Tau South, consistent with previous studies of infrared companions to T Tauri stars. Our results suggest that the near IR variability of T Tau S is probably caused by both variations in accretion rate and variable extinction along the line of sight.

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A molecular-line study of clumps with embedded high-mass protostar candidates

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We present molecular line observations made with the IRAM 30-m telecope of the immediate surroundings of a sample of 11 candidate high-mass protostars. These observations are part of an effort to clarify the evolutionary status of a set of objects which we consider to be precursors of UC HII regions.

In a preceding series of papers we have studied a sample of objects, which on the basis of their IR colours are likely to be associated with compact molecular clouds. The original sample of 260 objects was divided approximately evenly into a *High* group, with IR colour indices [25–12] $\geq$0.57 and [60–12] $\geq$1.3, and a *Low* group with complementary colours. The FIR luminosity of the *Low* sources, their distribution in the IR colour-colour diagram, and their lower detection rate in H_2O maser emission compared to the *High* sources, led to the hypothesis that the majority of these objects represent an earlier stage in the evolution than the members of the *High* group, which are mostly identifyable with UC HII regions. Subsequent observations led to the selection of 12 *Low* sources that have FIR luminosities indicating the presence of B2.5 to O8.5 V_0 stars, are associated with dense gas and dust, have (sub-)mm continuum spectra indicating temperatures of $\sim$30 K, and have no detectable radio continuum emission. One of these sources has been proposed by us to be a good candidate for the high-mass equivalent of a Class 0 object. In the present paper we present observations of the molecular environment of 11 of these 12 objects, with the aim to derive the physical parameters of the gas in which they are embedded, and to find further evidence in support of our hypothesis that these sources are the precursors to UC HII regions. We find that the data are consistent with such an interpretation.

All observed sources are associated with well-defined molecular clumps. Masses, sizes, and other parameters depend on the tracer used, but typically the cores have *average* diameters of $\sim$0.5–1 pc (with a range of 0.2 to 2.2 pc), and masses of a few tens to a few thousand solar masses. Compared to a similar analysis of *High* sources, the present sample has molecular clumps that are more massive, larger, cooler, and less turbulent. They also tend to have a smaller ratio of virial-to-luminous mass, indicating they are less dynamically stable than their counterparts in which the *High* sources are embedded. The large sizes suggest these clumps should still undergo substantial contraction (their densities are $\sim$10 times smaller than those of the *High* sources). The lower temperatures and small linewidths are also expected in objects in an earlier evolutionary state. In various sources indications are found for outflowing gas, though its detection is hampered by the presence of multiple emission components in the line spectra. There are also signs of self-absorption, especially in the spectra of ^{13}CO and HCO^+.

We find that the masses of the molecular clumps associated with our objects increase with L_{fir} ($M_{clump} \propto L_{fir}^{1.17}$), and that there is a (weak) relation between the clump mass and the mass of the embedded protostellar object $M_{proto} \propto M_{clump}^{0.30}$.

The large amount of observational data is necessarily presented in a compact, reduced form. Yet we supply enough information to allow further study. These data alone cannot prove or disprove the hypothesis that among these objects a high-mass protostar is truly present. More observations, at different wavelenghts and spatial resolutions are needed to provide enough constraints on the number of possible interpretations.

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Nebular thermal evolution and the properties of primitive planetary materials

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Models of the solar nebula are constructed to investigate the hypothesis that surviving planetary objects began to form as the nebula cooled from an early, hot epoch. The imprint of such an epoch might be retained in the spatial distribution of planetary material, the systematic deviations of its elemental composition from that of the Sun, chemical

indicators of primordial oxidation state, and variations in oxygen and other isotopic compositions. Our method of investigation is to calculate the time-dependent, two-dimensional temperature distributions within model nebulas of prescribed dynamical evolution, and to deduce the consequences of the calculated thermal histories for coagulated solid material. The models are defined by parameters which characterize nebular initial states (mass and angular momentum), mass accretion histories, and coagulation rates and efficiencies. It is demonstrated that coagulation during the cooling of the nebula from a hot state is expected to produce systematic heterogeneities which affect the chemical and isotopic compositions of planetary material. The radial thermal gradient at the midplane results in delayed coagulation of the more volatile elements. Vertical thermal gradients isolate the most refractory material and concentrate evaporated heavy elements in the gas phase. It is concluded that these effects could be responsible for the distribution of terrestrial planet masses, the systematic depletion patterns of the moderately volatile elements in chondritic meteorites and the Earth, the range of oxygen isotopic compositions exhibited by CAIs and other refractory inclusions, and some geochemical evidence for a moderately enhanced oxidation state. However, nebular fractionations on a global scale are unlikely to account for the more oxidizing conditions inferred for some CAIs and chondritic silicates, which require dust enhancements greater than a few hundred. This conclusion, along with the well-established evidence from studies of chondrules and CAIs for thermal excursions of short duration, make it likely that local environments, unrelated to nebular thermal evolution, were also important.

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Multi-transition study and new detections of class II methanol masers

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We have used the ATNF Mopra antenna and the SEST antenna to search in the directions of several class II methanol maser sources for emission from six methanol transitions in the frequency range 85-115 GHz. The transitions were selected from excitation studies as potential maser candidates. Methanol emission at one or more frequencies was detected from five of the maser sources, as well as from Orion KL. Although the lines are weak, we find evidence of maser origin for three new lines in G345.01+1.79, and possibly one new line in G9.62+0.20.

The observations, together with published maser observations at other frequencies, are compared with methanol maser modelling for G345.01+1.79 and NGC 6334F. We find that the majority of observations in both sources are consistent with a warm dust (175 K) pumping model at hydrogen density $\sim 10^6\,\mathrm{cm}^{-3}$ and methanol column density $\sim 5 \times 10^{17}\,\mathrm{cm}^{-2}$. The substantial differences between the maser spectra in the two sources can be attributed to the geometry of the maser region.

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Accretion Disks around Young Objects. III. Grain Growth

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We present detailed models of irradiated T Tauri disks including dust grain growth with power-law size distributions. The models assume complete mixing between dust and gas and solve for the vertical disk structure self-consistently including the heating effects of stellar irradiation as well as local viscous heating. For a given total dust mass, grain growth is found to decrease the vertical height of the surface where the optical depth to the stellar radiation becomes

unit and thus the local irradiation heating, while increasing the disk emission at mm and sub-mm wavelengths. The resulting disk models are less geometrically thick than our previous models assuming interstellar medium dust, and agree better with observed spectral energy distributions and images of edge-on disks, like HK Tau/c and HH 30. The implications of models with grain growth for determining disk masses from long-wavelength emission are considered.

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Singular Isothermal Disks: II. Nonaxisymmetric Bifurcations and Equilibria

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We review the difficulties of the classical fission and fragmentation hypotheses for the formation of binary and multiple stars. A crucial missing ingredient in previous theoretical studies is the inclusion of dynamically important levels of magnetic fields. As a minimal model for a candidate presursor to the formation of binary and multiple stars, we therefore formulate and solve the problem of the equilibria of isopedically magnetized, singular isothermal disks, without the assumption of axial symmetry. Considerable analytical progress can be made if we restrict our attention to models that are scale-free, i.e., that have surface densities that vary inversely with distance ϖ from the rotation axis of the system. In agreement with earlier analysis by Syer and Tremaine, we find that lopsided ($M = 1$) configurations exist at any dimensionless rotation rate, including zero. Multiple-lobed ($M = 2, 3, 4, ...$) configurations bifurcate from an underlying axisymmetric sequence at progressively higher dimensionless rates of rotation, but such nonaxisymmetric sequences always terminate in shockwaves before they have a chance to fission into $M = 2, 3, 4, ...$ separate bodies. On the basis of our experience in this paper, and the preceding Paper I, we advance the hypothesis that binary and multiple star-formation from smooth (i.e., not highly turbulent) starting states that are supercritical but in unstable mechanical balance requires the rapid (i.e., dynamical) loss of magnetic flux at some stage of the ensuing gravitational collapse.

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Extinct Radioactivities and Protosolar Cosmic-Rays: Self-Shielding and Light Elements

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We study the effects of self-shielding in the x-wind model of protosolar cosmic-ray irradiation of early solar-system rocks. We adopt a two-component picture of protoCAIs consisting of cores with the elemental abundances of type B1 CAIs (calcium-aluminum-rich inclusions) and mantles of less refractory material. The cores have a power-law distribution of sizes between $R_{\rm min}$ and $R_{\rm max}$. The mantles have a uniform thickness, whose value is chosen to bring the total inventory of elements at least as refractory as sulfur to cosmic abundances for the entire population of protoCAIs. Each object is irradiated with a fluence consistent with the product of their residence time in the reconnection ring and the flux of solar cosmic rays obtained by a scaling of impulsive flares from the hard X-rays observed from low-mass

protostars. For $R_{\rm min}$ in the 50 μm regime and $R_{\rm max}$ in the few cm regime, which corresponds to the range of sizes of observed CAIs in micrometeorites and chondrites, we recover approximately the canonical values quoted for the ratios ^{26}Al/^{27}Al, ^{53}Mn/^{55}Mn, and ^{41}Ca/^{40}Ca in CV3 meteorites. Moreover, the excess ^{138}La (denoted as ^{138}La*) produced by proton bombardment of ^{138}Ba lies within the CAI range obtained in the experiments of Shen *et al.* (1984, 2000; Shen & Lee 1998). When we include fragmentation reactions that produce ^{10}Be from the impact of protons, alphas, and ^{3}He on the ^{16}O that is bound up in rocks, we further obtain a level of ^{10}Be/^{9}Be that agrees approximately with the report of McKeegan *et al.* (2000a,b) for a CAI from the Allende meteorite. Similar calculations for the expected anomalies in the stable isotopes of lithium show rough consistency with the measured values and further support our interpretation. The value for ^{10}Be/^{9}Be is particularly difficult to produce by any other astrophysical mechanism. Thus, the ^{10}Be discovery greatly strengthens the case for an origin in early solar-system irradiation, rather than external stellar seeding, for the shortest-lived radionuclides inferred from CAIs in chondritic meteorites.

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Circumstellar Disks in the IC 348 Cluster

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We report the results of the first sensitive *L*-band (3.4 μm) imaging survey of the young IC 348 cluster in Perseus. In conjunction with previously acquired *JHK* (1.25, 1.65, 2.2 μm) observations, we use *L*-band data to obtain a census of the circumstellar disk population to $m_K = m_L \leq 12.0$ in the central ~ 110 arcmin^2 region of the cluster. An analysis of the *JHKL* colors of 107 sources indicates that 65% $\pm$ 8% of the cluster membership possesses (inner) circumstellar disks. This fraction is lower than those (86% $\pm$ 8% and 80% $\pm$ 7%) obtained from similar *JHKL* surveys of the younger NGC 2024 and Trapezium clusters, suggesting that the disk fraction in clusters decreases with cluster age. Sources with circumstellar disks in IC 348 have a median age of 0.9 Myr, while the diskless sources have a median age of 1.4 Myr, for a cluster distance of 320 pc. Although the difference in the median ages between the two populations is only marginally significant, our results suggest that over a timescale of $\sim 2 - 3$ Myr, more than a third of the disks in the IC 348 cluster disappear. Moreover, we find that at a very high confidence level, the disk fraction is a function of spectral type. All stars earlier than G appear diskless, while stars with spectral types G and later have a disk fraction ranging between 50% – 67%, with the latest type stars having the higher disk fraction. This suggests that the disks around stars with spectral types G and earlier have evolved more rapidly than those with later spectral types. The *L*-band disk fraction for sources with similar ages in both IC 348 and Taurus is the same, within the errors, suggesting that, at least in clusters with no O stars, the disk lifetime is independent of environment.

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Preprints available from astro-ph/0101486

From infall to rotation around young stellar objects: A transitional phase with a 2000 AU radius contracting disk?

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Evidence for a transitional stage in the formation of a low-mass star is reported, intermediate between the fully embedded and the T Tauri phases. Millimeter aperture synthesis observations in the HCO^+ J=1–0 and 3–2, HCN 1–0, ^{13}CO 1–0, and C^{18}O 1–0 transitions reveal distinctly different velocity fields around two embedded, low-mass young stellar objects. The 0.6 $M_\odot$ of material around TMC 1 (IRAS 04381+2517) closely follows inside-out collapse in the presence of a small amount of rotation (~ 3 km s^{-1} pc^{-1}), while L1489 IRS (IRAS 04016+2610) is surrounded by a 2000 AU radius, flared disk containing 0.02 $M_\odot$. This disk shows Keplerian rotation around a ~ 0.65 $M_\odot$ star and infall at $1.3(r/100\,\mathrm{AU})^{-0.5}$ km s^{-1}, or, equivalently, sub-Keplerian motions around a central object between 0.65

and 1.4 $M_\odot$. Its density is characterized by a radial power law and an exponential vertical scale height. The different relative importance of infall and rotation around these two objects suggests that rotationally supported structures grow from collapsing envelopes over a few times 10^5 yr to sizes of a few thousand AU, and then decrease over a few times 10^4 yr to several hundred AU typical for T Tauri disks. In this scenario, L1489 IRS represents a transitional phase between embedded YSOs and T Tauri stars with disks. The expected duration of this phase of $\sim 5\%$ of the embedded stage is consistent with the current lack of other known objects like L1489 IRS. Alternative explanations cannot explain L1489 IRS's large disk, such as formation from a cloud core with an unusually large velocity gradient or a binary companion that prevents mass accretion onto small scales. It follows that the transfer and dissipation of angular momentum is key to understanding the formation of disks from infalling envelopes.

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Preprints available at `http://astro.berkeley.edu/~michiel/pub.html`

Intrinsic Shapes of Molecular Cloud Cores

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We conduct an analysis of the shapes of molecular cloud cores using recently compiled catalogs of observed axis ratios of individual cores mapped in ammonia or through optical selection. We apply both analytical and statistical techniques to de-project the observed axis ratios in order to determine the true distribution of cloud core shapes. We find that neither pure oblate nor pure prolate cores can account for the observed distribution of core shapes. Intrinsically triaxial cores produce distributions which agree with observations. The best fit triaxial distribution contains cores which are more nearly oblate than prolate.

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A Three Micron Survey of the Chamaeleon I Dark Cloud

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We describe an L-band photometric survey of ~ 0.5 deg^2 of the Cha I dark cloud. The survey has a completeness limit of $L < 11.0$. Our survey detects 124 sources, including all known pre-main sequence stars with $L \leq 11$. The fraction of sources with near-IR excess emission is $58\% \pm 4\%$ for K = 9–11. Cha I sources have bluer $H-K$ and $K-L$ colors than pre-main sequence stars in Taurus-Auriga. These sources also have a strong correlation between EW(Hα) and $K-L$. Stars with $K-L \leq 0.6$ have weak Hα emission; stars with $K-L \geq 0.6$ have strong Hα emission. Because many Cha I sources are heavily reddened, this division between weak emission T Tauri stars and classical T Tauri stars occurs at a redder $K-L$ than in Taurus-Auriga.

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Disks around Hot Stars in the Trifid Nebula

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We report on mid-IR observations of the central region in the Trifid nebula, carried out with ISOCAM in several broad-band infrared filters and in the low resolution spectroscopic mode provided by the circular variable filter. Analysis of the emission indicates the presence of a hot dust component (500 to 1000 K) and a warm dust component at lower temperatures ($\sim 150 - 200$ K) around several members of the cluster exciting the HII region, and other stars undetected at optical wavelengths. Complementary VLA observations suggest that the mid-IR emission could arise from a dust cocoon or a circumstellar disk, evaporated under the ionization of the central source and the exciting star of the nebula. In several sources, the 9.7μm silicate band is seen in emission. One young stellar source shows indications of crystalline silicates in the circumstellar dust.

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A far infrared view of low mass star formation in the Cederblad 110 nebula of Chamaeleon I

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The Cederblad 110 reflection nebula contains several young stellar objects previously discovered by IRAS and sub-mm observations. This cluster was revisited with ISO's FIR cameras and mapped with higher spatial resolution. All sources were also mapped for the first time near the maximum of their spectral energy distribution at 200 μm. In addition, two new FIR-sources were discovered. The new data enabled parameters of the young objects to be determined, such as their luminosity, temperature and mass of the circumstellar dust. These parameters were related to the YSO classes of the various objects ranging from the pure protostar Class O to Class III. Cederblad 110 can be viewed as a compact volume of active low mass star formation in a dense ridge of molecular gas of the Chamaeleon I cloud detected e.g. in $HN^{13}C$ and $C^{18}O$ lines. The star formation efficiency in the 0.001pc^3 cluster volume is high; about 20% of the gas is now bound into stars.

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The near-infrared and ice-band variability of Haro 6-10

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We have monitored the angularly resolved near infrared and 3.1 μm ice-band flux of the components of the young binary Haro 6-10 on 23 occasions during the years 1988 to 2000. Our observations reveal that both the visible star Haro 6-10 (Haro 6-10S) and its infrared companion (Haro 6-10N) show significant variation in flux on time scales as short as a month. The substantial flux decrease of Haro 6-10S over the last four years carries the reddening signature of increased extinction. However, a comparable K-band flux increase observed in the IRC is associated with a dimming in the H-band and cannot be explained by lower extinction. Absorption in the 3.1 μm water-ice feature was always greater towards the IRC during our observations, indicating a larger amount of obscuring material along its line of sight. We detect variability in the ice-band absorption towards Haro 6-10S and Haro 6-10N, significant at the 3.5σ and 2.0σ levels, respectively.

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An extraordinary accretion event detected on DF Tau

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We report on the detection of an extreme flare-like event on DF Tau, during a spectroscopic monitoring program of some classical T Tauri stars known to show hot spots on their surface. These observations were performed on a nightly basis within roughly one rotational period of DF Tau between Jan. 7 and 14, 2000. The estimated amplitude of variation during this time reached up to 6 mag in the B band. Significant inverse P Cygni profiles in high Blamer lines – evidence of mass accretion – dominated the spectrum obtained on Jan. 8, when the brightness of DF Tau was approaching its maximum. The flux in the ultraviolet dropped dramatically on the following day. CaII H and K emission lines, the indicator of chromospheric activity, turned into deep, wide absorption and all other emission lines in the blue end were also absent (filled-in or weak absorption), suggesting severe absorption in the line of sight possibly caused by a transient envelope produced in process of violent accretion shock. The effect of veiling decreased rapidly from Jan. 10 and normal P Cygni profiles, indicating the presence of strong wind, began to appear. Based on the unique features displayed, we propose the spectroscopic record of this flare-like brightening on DF Tau, believed to be due to episodic mass accretion accompanied by the release of gravitational energy, might actually be taken as an isolated, snap-shot view of the Y Y Orionis phenomenon.

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Search for spectroscopical signatures of transiting HD209458b's exosphere

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Following recent attempts to detect the exosphere of the extra-solar planet 51 Pegb in the infrared (Coustenis et al. 1997 & 1998, Rauer et al. 2000a), we discuss here a search for optical spectroscopic signatures from a gaseous extended envelope (called exosphere) surrounding the planet HD209458b. This planet has a demonstrated photometric transit (Charbonneau et al. 2000a, Henry et al. 2000), thus offering an increased probability for the spectroscopic detection of such an envelope. Therefore it is the best known candidate for probing the exospheric composition of a giant planet, orbiting a Sun-like star at a short distance. The observations were performed with UVES at the VLT and cover most of the 328 – 669 nm range. We did not detect HD209458b's exosphere at a level of 1%, a value close to the predictions. We discuss here the first results obtained and their limitations, as well as future prospective.

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Binary Masses as a Test for Pre–Main-Sequence Tracks

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Observations of binaries have traditionally provided the means for ascertaining stellar masses. Here, we use the published data on 8 pre–main-sequence pairs to gauge the accuracy of our own, recently calculated, evolutionary tracks (Palla & Stahler 1999). We consider both eclipsing, double-lined spectroscopic binaries, which provide the mass of each star separately, and non-eclipsing, double-lined systems, which yield only the ratio. We also analyze the visual, quadruple system GG Tau, for which the sum of the two component masses follows from observations of the circumbinary disk.

In almost all cases, our theoretically derived masses or mass ratios are in good agreement with the empirical values. For two binaries (NTTS 162814−2427 and P1540), the observational results are still too uncertain for a proper comparison. We also find that the derived contraction ages within each pre–main-sequence pair are nearly equal. This result extends earlier findings regarding visual pairs, and indicates that the components of all binaries form in proximity, perhaps within the same dense cloud core. Finally, our study reveals that the Trapezium star BM Ori is very young, since both the star itself and its companion have contraction ages less than 10^5 years.

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The ps file can be obtained at: http://www.arcetri.astro.it/∼starform/publ2001.htm

Keck Diffraction-Limited Imaging of the Young Quadruple Star System HD 98800

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This paper presents diffraction-limited 1−18μm images of the young quadruple star system HD 98800 obtained with the W. M. Keck 10-m telescopes using speckle and adaptive optics imaging at near-infrared wavelengths and direct imaging at mid-infrared wavelengths. The two components of the visual binary, A and B, both themselves spectroscopic binaries, were separable at all wavelengths, allowing us to determine their stellar and circumstellar properties. Combining these observations with spectroscopic data from the literature, we derive an age of $\sim10^7$ years, masses of 0.93 and 0.64 $M_\odot$ and an inclination angle of 58° for the spectroscopic components of HD 98800 B, and an age of $\sim10^7$ years and a mass of 1.1 $M_\odot$ for HD 98800 Aa. Our data confirm that the large mid-infrared excess is entirely associated with HD 98800 B. This excess exhibits a black body temperature of 150 K and a strong 10μm silicate emission feature. The theoretical equilibrium radius of large, perfectly absorbing, 150 K grains around HD 98800 B is 2.4 AU, suggesting a circum-spectroscopic binary distribution. Our observations set important upper limits on the size of the inner dust radius of ∼2 AU (from the mid-infrared data) and on the quantity of scattered light of <10% (from the H-band data). For an inner radius of 2 AU, the dust distribution must have a height of at least 1 AU to account for the fractional dust luminosity of ∼20% L_B. Based on the scattered light limit, the dust grains responsible for the excess emission must have an albedo of <0.33. The presence of the prominent silicate emission feature at 10μm implies dust grain radii of $\gtrsim$2μm. The total mass of the dust is >0.002$M_\oplus$. We conclude that the dust is located in a circumbinary disk around the HD 98800 B spectroscopic binary with an inner gap of ∼2 AU and a height of $\gtrsim$1 AU and we speculate that the A−B orbital dynamics are responsible for the characteristics of the observed dust in the system.

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A large spectroscopic survey for young low-mass members of the Upper Scorpius OB Association

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We present the results of a large intermediate-resolution spectroscopic survey for pre-main sequence (PMS) stars in the Upper Scorpius OB association, the most nearby region of recent massive star formation. Utilizing the multi-object spectrograph 2dF at the Anglo-Australian-Telescope, we obtained spectra of 576 stars with magnitudes $R = [12.5 \ldots 16.5]$ in a 6 square-degree area in Upper Scorpius. Among these objects we were able to identify 98 new PMS stars, nearly all of them M-type stars, by their strong lithium absorption lines. We place the new PMS stars into the

HR diagram and find that their ages agree well with the mean age of 5 Myr determined in our earlier investigation (Preibisch & Zinnecker 1999) based on a smaller sample of stars. The number of low-mass ($M_\star \sim [0.1 \ldots 0.5]\, M_\odot$) members is at least as high as expected from the know number of high-mass ($M_\star \geq 3\, M_\odot$) association members and recent determinations of the field star IMF. Thus, there is no deficit of low-mass stars in Upper Scorpius.

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Preprints are available at http://www.mpifr-bonn.mpg.de/staff/tpreibis/publications.html

Photometry and polarimetry of the classical Herbig Ae star VV Ser

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We present the results of our long-term photometric and polarimetric observations of the classical Herbig Ae star VV Ser, performed at the Crimean Astrophysical Observatory as part of a program of photopolarimetric monitoring of UX Ori-type stars. We recorded an unusually deep minimum of VV Ser ($\Delta V \approx 3^m$) with a turn of the color tracks in the V vs. (U-B) and V vs. (B-V) diagrams ("the blueing effect") observed for the first time for this star. The increase of the linear polarization during the minimum brightness was consistent with expectations for variable circumstellar extinction models, and the maximum polarization in the B-band reached a record value for UX Ori stars in the deepest part of the minimum (12.8 $\pm$1.4%). Our results cannot be explained by models with an axially symmetrical circumstellar dust disk consisting of silicate grains. They point to the existence of a large-scale nonuniformity in the azimuthal dust distribution near VV Ser attributable to the presence of a second component or massive protoplanet.

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The Origin of Chondrules and Refractory Inclusions in Chondritic Meteorites

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Examples of calcium-aluminum-rich inclusions (CAIs) surrounded by thick chondrule mantles have been found in chondritic meteorites and cast doubt on the conventional belief that CAIs and chondrules possessed different spacetime origins in the primitive solar nebula. We study specific processes by which such objects, and the more common ordinary CAIs and chondrules, might have formed by flare heating of primitive rocks interior to the inner edge of a gaseous accretion disk that has been truncated by magnetized funnel flow onto the central protosun. Motivated by the appearance of the chains of Herbig-Haro knots that define collimated optical jets from many young stellar objects (YSOs), we adopt the model of a fluctuating x-wind, where the inner edge of the solar nebula undergoes periodic radial excursions on a time scale of ~ 30 yr, perhaps in response to protosolar magnetic cycles. Flares induced by the stressing of magnetic fields threading both the star and the inner edge of the fluctuating disk melt or partially melt solids in the transition zone between the base of the funnel flow and the reconnection ring, and in the reconnection ring itself. The rock melts stick when they collide at low velocities. Surface tension pulls the melt aggregate into a quasi-spherical core/mantle structure, where the core consists mainly of refractories and the mantle mainly of moderate volatiles. Orbital drift of rocks past the inner edge of the disk or infall of large objects from the funnel flow replaces the steady loss of material by the plasma drag of the coronal gas that corotates with the stellar magnetosphere. In quasi-steady state, agglomeration of molten or heat-softened rocks leads to a differential size-distribution in radius R

proportional to $R^{-3}e^{-Lt/t_L R}$, where $t_L \sim 20$ yr is the drift time of an object of fiducial radius $L \equiv 1$ cm, and t is the time since the last inward excursion of the base of the funnel flow and x-wind. Thus, during the ~ 30 yr interval between successive flushing of the reconnection ring, flash-heated and irradiated rocks have a chance to grow to mm and cm sizes. The evaporation of the moderately volatile mantles above large refractory cores, or the dissolving of small refractory cores inside thick ferromagnesian mantles before launch, plus extended heating in the x-wind produce the CAIs or chondrules that end up at planetary distances in the parent bodies of chondritic meteorites.

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Early dust evolution in protostellar accretion disks

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We investigate dust dynamics and evolution during the formation of a protostellar accretion disk around intermediate mass stars via 2D numerical simulations. Using three different detailed dust models, compact spherical particles, fractal BPCA grains, and BCCA grains, we find that even during the early collapse and the first $\sim 10^4$ yr of dynamical disk evolution, the initial dust size distribution is strongly modified. Close to the disk's midplane coagulation produces dust particles of sizes of several 10 μm (for compact spherical grains) up to several mm (for fluffy BCCA grains), whereas in the vicinity of the accretion shock front (located several density scale heights above the disk), large velocity differences inhibit coagulation. Dust particles larger than about 1 μm segregate from the smaller grains behind the accretion shock. Due to the combined effects of coagulation and grain segregation the infrared dust emission is modified. Throughout the accretion disk a MRN dust distribution provides a poor description of the general dust properties. Estimates of the consequences of the "freezing out" of molecules in protostellar disks should consider strongly modified grains. Physical model parameters such as the limiting sticking strength and the grains' resistivity against shattering are crucial factors determining the degree of coagulation reached. In dense regions (e.g. in the mid-plane of the disk) a steady-state is quickly attained; for the parameters used here the coagulation time scale for 0.1 μm dust particles is ~ 1 yr (10^{-12} g cm$^{-3}/\varrho$). High above the equatorial plane coagulation equilibrium is not reached due to the much lower densities. Here, the dust size distribution is affected primarily by differential advection, rather than coagulation. The influence of grain evolution and grain dynamics on the disk's near infrared continuum appearance during the disk's formation phase is only slight, because the most strongly coagulated grains are embedded deep within the accretion disk.

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Diagnostics of accretion disk of UX Ori based on the study of hydrogen lines of Balmer, Paschen and Brackett series

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On the base of spectra obtained with Nordic Optical Telescope and NASA Infrared Telescope Facility the modeling of the hydrogen lines of Balmer (H_α, H_β, H_γ), Paschen (P14) and Brackett (Br_γ) series arising in the inner regions of the accretion disk of Herbig Ae star UX Ori are carried out. For this, a grid of non-LTE models of accretion disks has been computed using the Sobolev method and the main characteristics of the considered lines have been determined.

An analysis of the theoretical and observed line profiles as well as their equivalent widths and luminosities permited us to determine the accretion rate and the electron temperature distribution in the inner parts of accretion disk. Accretion rate for UX Ori is about $\dot{M} = (3 \div 10) \cdot 10^{-9} M_\odot$ per yr and the temperature law $T(r) = T(r_*)(r/r_*)^{-1/n}$

gives the best results where the electron temperature near the star $T(r_*)$ is likely between 15000 - 20000 and the power index n is about 2 - 3.

Such values of accretion rates avoid contradictions arised when applying the model of the magnetospheric accretion to Herbig Ae/Be stars. Another important conclusion is that the energy released at that accretion rate is significantly lower (by about two orders) than the luminosities of the stars. Therefore, the radiation of UX Ori type accretion disks in the visible part of the spectrum cannot contribute essentially to the observed variability of these stars; the latter is determined mainly by the variable circumstellar extinction.

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Mid-infrared Observations of Methanol Maser Sites and Ultracompact HII regions: Signposts of High-Mass Star Formation

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N-band (10.5 μm) and/or Q-band (20.0 μm) images taken with MANIAC on the ESO/MPI 2.2 m telescope are presented for 31 methanol maser sites and 19 ultracompact (UC) HII regions. Most of the maser sites and UC HII regions are coincident with mid-infrared (MIR) sources to within the positional uncertainties of $\sim$3 arcsec, consistent with the maser emission being powered by the MIR source. The *IRAS* source positions however do not always coincide with the MIR sources.

Based on an average infrared spectral energy distribution, we deduce that the MIR objects are luminous enough that they should also produce a strong ionising radiation. Some sources are consistent with later spectral type stars, but not all can be. A number of maser sites show no detectable radio continuum emission associated with MIR emission despite a powering source luminous enough to potentially produce an UC HII region. Since no signs of an UC HII region are detected here, these maser sites might be produced during a very early stage of stellar evolution.

We present objects which show evidence of outflow activity stemming from a maser site, exhibiting CO and/or CS line profiles indicative of outflows coincident with the MIR source. These cases are promising examples of maser sites signposting the earliest stages of high-mass star formation.

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preprint at: http://www.mpifr-bonn.mpg.de/staff/awalsh/maniac/maniac.tar.gz

The Flattened, Rotating Molecular Gas Core of Protostellar Jet HH 212

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The recently discovered protostellar jet known as HH212 is beautifully symmetric, with a series of paired shock knots and bow shocks on either side of the exciting source region, IRAS 05413-0104 (Zinnecker *et al.* 1998). We present VLA ammonia maps of the IRAS 05413-0104 molecular gas envelope in which the protostellar jet source is embedded. We find that the envelope, with mass of 0.2 $M_\odot$ detected by the interferometer, is flattened perpendicular to the jet axis with a FWHM diameter of 12000 AU and an axis ratio of 2:1, as seen in NH_3 (1,1) emission. There is a velocity gradient of about 4-5 km sec^{-1} pc^{-1} across the edge-on flattened core, suggestive of rotation around an axis aligned with the jet. Rotational velocities increase smoothly with radius at a roughly constant velocity gradient rather than showing a Keplerian profile. In young (Class 0) systems such as HH212, a significant amount of material is still distributed in a large surrounding envelope, and thus the observable kinematics of the system may reflect the less centrally condensed, youthful state of the source and obscuration of central dynamics. The angular momentum of this envelope material

may be released from infalling gas through possible rotation in the HH212 jet, as recent observations suggest (Davis *et al.* 2000). A blue-shifted wisp or bowl of emitting gas appears to be swept up along the blue side of the outflow, possibly lining the cavity of a wider angle wind around the more collimated shock jet axis. Our ammonia (2,2)/(1,1) ratio map indicates that this very cold core is heated to 14 Kelvin degrees in a centrally condensed area surrounding the jet source. This edge-on core and jet system appears to be young and deeply embedded. This environment, however, is apparently not disrupting the pristine symmetry and collimation of the jet.

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Preprints available at http://www.pha.jhu.edu/∼jwiseman/

Orbital motion in T Tauri binary systems

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Using speckle-interferometry we have carried out repeated measurements of relative positions for the components of 34 T Tauri binary systems. The projected separation of these components is low enough that orbital motion is expected to be observable within a few years. In most cases orbital motion has indeed been detected. The observational data is discussed in a manner similar to Ghez et al. (1995). However, we extend their study to a larger number of objects and a much longer timespan. The database presented in this paper is valuable for future visual orbit determinations. It will yield empirical masses for T Tauri stars that now are only poorly known. The available data is however not sufficient to do this at the present time. Instead, we use short series of orbital data and statistical distributions of orbital parameters to derive an average system mass that is independent of theoretical assumptions about the physics of PMS stars. For our sample this mass is $2.0\,M_{\odot}$ and thus in the order of magnitude one expects for the mass sum of two T Tauri stars. It is also comparable to mass estimates obtained for the same systems using theoretical PMS evolutionary models.

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http://www.tls-tautenburg.de/research/tls-research/pub2001.html

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, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

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Dissertation Abstracts

The Dynamics of Outflows from Young Stellar Objects

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Ph.D degree awarded: January 2001

The prevalence of CO outflows around young stellar objects (YSOs) suggests that mass-loss is a necessary ingredient of the star-formation process, and they are thought to provide a means to remove angular momentum from the accreting matter. Our understanding of molecular outflows from low-mass YSOs has come from a large number of studies performed during the last decade. However there have been relatively few similar detailed studies of high-mass YSO outflows, and it is still not clear whether outflows from high-mass YSOs are generated and entrained by the same mechanism as those from their low-mass counterparts.

Studies of high-mass star-formation which attempt to extend the established correlations between outflow momentum-flux and source bolometric luminosity into the high-mass regime are further hindered by the problem of Malmquist bias, which we show to be prevalent in the existing studies of high-mass YSOs. We therefore selected a sample of known intermediate to high-mass YSOs with outflows with a range of luminosities but all located at a distance of 2 ± 0.3 kpc. With this sample we are able to test the correlations between outflow dynamical properties and source properties free from biases due to source distance, and to investigate whether the other phenomena associated with low-mass YSO outflows are also common in high-mass flows.

We present high-sensitivity ^{12}CO maps of the 11 outflows from intermediate to high-mass YSOs, and discuss their morphology and dynamics. These data were also used to re-investigate the uncertainties involved in using spectral-line data to derive flow properties, particularly the importance of variations in optical depth and the problem of separating ambient cloud emssion from flow emission. We also present ^{13}CO and C^{18}O observations of the "cores" surrounding each YSO and discuss how the cloud core and outflow may be related.

The primary conclusions of this work are:

- The correlation between outflow momentum flux (F_{rmCO}) and source bolometric luminosity ($\mathrm{L}_{\mathrm{bol}}$) is less well-established for high-mass YSOs than has previously been accepted.
- Outflows from high-mass YSOs show a much larger range ($\sim$1 to $\sim$12) of γ, the slope of the mass-velocity relation than their low-mass counterparts, and show no Hubble-like law. They are also in general much more poorly collimated than outflows from low-mass YSOs.
- The correlation between outflow power and source bolometric luminosity may be purely due to an underlying relation between cloud core mass and flow mass, suggesting that the dynamical properties of molecular material may tell us nothing about the generation and entrainment of the flow.
- The choice of velocity cut-off between flow material and ambient cloud material dominates the uncertainty in masses derived from ^{12}CO observations, and may increase the uncertainty in the derived flow mass by a factor of $\sim$10 greater than estimates by previous studies which have not recognised this problem.

New Jobs

Star Formation Group of the Osservatorio Astrofisico di Arcetri

Postdoctoral position available

In the framework of the European Commission Research Training Network entitled "The Formation and Evolution of Young Stellar Clusters" (see `http://www.aip.de/~mjm/ecrtn_clusters/`), a postdoctoral position is available for two years in the Star Formation Group of the Osservatorio Astrofisico di Arcetri, Firenze, Italy.

Arcetri is a major research institute involving about 50 staff members, post-docs and students with a strong focus on interstellar medium and star formation, both theoretical and observational.

The Star Formation Group includes 14 permanent staff members, 2 post-docs and 1 student. A description of the activities of the institute and of the Star Formation Group can be found at: `http://www.arcetri.astro.it/~starform/`. Our main interests are:

- the initial conditions for cluster formation;
- the formation of massive stars in clusters;
- pre-main sequence evolution of low- and intermediate-mass stars;
- the structure and evolution of circumstellar disks and outflows.

The observational activities involve extensive use of the ESO, IRAM and NRAO facilities, and of the national observatories (Telescopio Nazionale Galileo, Medicina radiotelescope, Tirgo telescope). As part of the EC Research Training Network, the star formation group also has collaborative access to British, French, German, and Portuguese facilities.

We welcome people interested in the study of cluster formation and evolution, circumstellar disks around young stars, jets and outflows. The successful applicant is expected to take an active role in an ongoing effort to improve our understanding of the formation and early evolution of young stars and their environment. Applicants should have a Ph.D. and observational or theoretical experience in young stellar objects, or related fields. They should be 35 or under at the time of appointment, be a national of a European Community member or associated state other than Italy or have lived in the EC for at least five years before appointment; and not have lived in Italy for more than 12 of the 24 months prior to appointment. The position is available immediately but the starting date is flexible.

The net salary, after deduction of charges, medical coverage, etc. will be around 3.2–3.6 MLit/month (1700–1900 euros/month).

Interested scientists should submit a curriculum vitae, a list of publications and a statement of research interests, and should indicate the names of three experts in the field for reference. Applications should be sent to:

Daniele Galli
Osservatorio Astrofisico di Arcetri
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Review of applications will begin on 15 February 2001 and continue until the position is filled.

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Research Fellows (2) in Theoretical Astrophysics

The Astronomy group in the School of Physics and Astronomy at the University of St Andrews invites applications for two postdoctoral positions in theoretical astrophysics. We are particularly interested in candidates working in one or more of the following areas: formation of stars, planets, and stellar clusters, protoplanetary disks, computational hydrodynamics or radiative transfer. You must have a Ph.D. and a demonstrated ability to pursue independent research. The positions are funded for three years on the UK salary scale 1A for Research Staff (sterling 16,775-25,213 per annum), and include support for travel and computing.

Application packs and further particulars are available from Personnel Services, University of St Andrews, College Gate, North Street, St Andrews, Fife KY16 9AJ, United Kingdom. (Tel: +44-1334-462571, FAX +44-1334-462570, email Jobline@st-andrews.ac.uk). **Please quote reference SK077/9148/01**. Closing date 1st April 2001.

We regret that applications cannot be made by email. However, informal enquiries may be addressed to Ian Bonnell (iab1@st-andrews.ac.uk) or Phil Armitage (pja3@st-andrews.ac.uk).

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.

New Books

Solid Interstellar Matter: The ISO Revolution

Editors L. d'Hendecourt, C. Joblin, A. Jones

These are the lectures of a Les Houches School of Physics, held in Les Houches, France in February 1998. One of the areas where the Infrared Space Observatory has had most impact and success is in the domain of the chemistry of the interstellar medium. This school gathered young scientists active in this field together with others specializing on ISO observations and data reduction, and some working on laboratory spectroscopy of dust. Most of the twenty lectures provide an introduction to the subject with references to the key literature, followed by a detailed discussion of the impact of specific new ISO observations. Other lectures give broader reviews, and those based on laboratory results provide a sort of reference frame in which the astronomical data can be interpreted. Combined, the lectures give a fascinating overview of what is rightfully dubbed the ISO revolution in interstellar dust studies.

GENERAL OBSERVATIONS OF DUST

1. *Interplanetary Dust as seen in the Zodiacal Light with ISO* P. Ábrahám et al.
2. *Small Dust Particles in the ISM* F. Boulanger
3. *Properties of Dust in High Latitude Clouds* R.J. Laureijs
4. *Very Cold Dust in Star Forming Regions* I. Ristorcelli et al.

CARBON IN DUST

5. *Polycyclic Aromatic Hydrocarbons in the Interstellar Medium: A Review* F. Salama
6. *PAHs in Reflection Nebula, Fullerenes in the ISM* C. Moutou et al.
7. *Present situation of the Coal model for Interstellar Carbon Dust* O. Guillois e al. 8. *Organics in the ISM: Where Do They Come From?* Y.J. Pendleton
9. *Laboratory Analogues for Interstellar Carbon Dust* L. Colangeli et al.

COLD DUST: ICES AND SILICATES

10. *Combined SWS-LWS Spectra of Solid State Features* P. Cox & P.R. Roelfsema
11. *Molecules in the Gas and Solid State towards the Young Massive Protostar RAFGL7009S* E. Dartois et al.
12. *Ice Evolution in the Interstellar Medium* W.A. Schutte
13. *The Physics and Chemistry of Ices in the Interstellar Medium* M.H. Moore
14. *Crystalline Silicates in Circumstellar Shells* L.B.F.M. Waters et al.
15. *Comparison of Ices and Silicates in Comets and in the Interstellar Medium* P. Ehrenfreund

DUST PROCESSING

16. *Grain Formation and Evolution in the Interstellar Medium* Th. Henning
17. *Emission from Carbon-Rich Stellar Envelopes* R.J. Sylvester
18. *ISO Observations of Vega-Like Stars* C. Dominik
19. *Dust Formation in Supernovae* P.O. Lagage et al.

INTERSTELLAR MATTER IN THE LABORATORY?

20. *Mg-Rich Olivine and Pyroxene Grains in Primitive Meteoritic Materials: Comparison with Crystalline Silicate Data from ISO* J.P. Bradley et al.

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ISO Surveys of a Dusty Universe

Editors D. Lemke, M. Stickel, K. Wilke

These are the proceedings of a workshop held at Ringberg Castle in germany in November 1999. With the ISO mission successfully completed, several meetings have been dedicated to analyze and discuss the large amounts of data that were acquired. ISO was an observatory mission dedicated to completing a large number of peer selected observing programs, in contrast to IRAS, which was dedicated to an all sky survey. In this sense ISO was a not a survey project, but when combining results from the many individual programs, it is indeed possible to talk about the ISO surveys, and this book is devoted to a review of the results and prospects for future results when comparing large samples of similar objects. With the release of all the ISO data and unlimited access to ESA's data archive, the possibilities for extracting large and relatively homogeneous data sets are numerous. This book is devoted to an examination of already achieved by ISO surveys, and of ongoing and planned survey projects.

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VII. Present and Future Surveys

Among the presentations specifically relevant for the star formation community are:

An ISOPHOT Survey of Pre-Stellar Cores D. Ward-Thompson & Ph. André
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Astrophysical Formulae

Volume I: Radiation, Gas Processes and High Energy Astrophysics

Kenneth R. Lang

This is the third edition of Kenneth Lang's famous reference book, which originally appeared in 1974 and, like Allen's *Astrophysical Quantities*, has become an indispensable tool for all astrophysicists. The present work has been revised, updated and re-organized and, with more than a doubling of the number of formulae and references, the book has been divided into two volumes, the one presented here, and a Volume II on space, time, matter and cosmology. In all, there is now more than 4000 formulae. The thousands of references are now, in contrast to previous editions, conveniently gathered at the end of each volume in alphabetical order. *Astrophysical Formulae* has become justifiably famous among astronomers and astrophysicists because it is useful in so many different ways. If one just needs a formula, it is quickly found. If one wants more details, many of the formulae are derived from basic principles. If one wants an overview of an unfamiliar area, all the fundamental results are summarized. And if one wants to know the history and development of a subject, the original references are listed along with the more recent ones.

Volume I, which is the one most relevant for people working in star formation and the interstellar medium, is divided into the following sections:

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3.5 Gas Macrostructure - Hydrodynamics
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