

THE STAR FORMATION NEWSLETTER

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From the Editor

The Star Formation Newsletter has since its inception been devoted to star formation processes, molecular clouds and the interstellar medium within our Galaxy. More recently, the Large and Small Magellanic Clouds were added, since we have reached the point where even individual low mass stars can be fruitfully studied in these neighboring galaxies (see the abstract of Wichmann et al. in this issue). However, increases in telescope sizes and developments in detector technology and in high-resolution techniques continue, and we are likely soon to see studies of young stellar populations in nearby galaxies which are highly relevant to the more detailed studies performed in our own Galaxy. Consequently, the Star Formation Newsletter will from now on accept abstracts dealing with star formation, molecular clouds and the interstellar medium also in *nearby* galaxies. In a way it would be desirable to include such studies for *all* galaxies, but practical constraints and a desire to keep the Newsletter within a manageable size precludes this. Thus a distance limit must be imposed, which necessarily will be somewhat arbitrary. For now I have chosen to say that abstracts dealing with star formation within the nearest 8 Mpc will be included, guided by the fact that our Local Group and most of the brightest galaxies in the sky are then included, and by a feeling that star formation studies in these nearby Galaxies are likely to be important for an understanding of star formation in our own Galaxy. The first such abstract is presented by Lamers et al. in this issue.

Abstracts of recently accepted papers

The Formation of the First Star in the Universe

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We describe results from a fully self-consistent three dimensional hydrodynamical simulation of the formation of one of the first stars in the Universe. As dark matter dominated pre-galactic objects form because of gravitational instability from small initial density perturbations. As they assemble via hierarchical merging, primordial gas cools through ro-vibrational lines of hydrogen molecules and sinks to the center of the dark matter potential well. The high redshift analog of a molecular cloud is formed. As the dense, central parts of the cold gas cloud become self-gravitating, a dense core of $\sim 100 M_{\odot}$ undergoes rapid contraction. At densities $n > 10^9 \text{ cm}^{-3}$ a $1 M_{\odot}$ proto-stellar core becomes fully molecular due to three-body H_2 formation. Contrary to analytical expectations this process does not lead to renewed fragmentation and only one star is formed. The calculation is stopped when optical depth effects become important, leaving the final mass of the fully formed star somewhat uncertain. At this stage the protostar is accreting material very rapidly ($\sim 10^{-2} M_{\odot} \text{ yr}^{-1}$). Radiative feedback from the star will not only halt its growth but also inhibit the formation of other stars in the same pre-galactic object (at least until the first star ends its life, presumably as a supernova). We conclude that at most one massive ($M \gg 1 M_{\odot}$) metal free star forms per pre-galactic halo, consistent with recent abundance measurements of metal poor galactic halo stars.

Accepted by Science

More results, images and movies can be found at www.TomAbel.com.

Constraints on circumstellar disk parameters from multi-wavelength observations: T Tau and SU Aur

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We present circumstellar disk models for two pre-main sequence objects, T Tau and SU Aur. The models are based on interferometric data from infrared and millimeter wavelengths and infrared photometry from the literature. The physical properties of the disk are examined by calculating parameter probabilities based on a passive, flat disk model. The model adequately fits the data for SU Aur, but not for T Tau. We find that there are significant differences in the physical parameters suggested by the individual data sets. The size of the inner disk radius as implied by the infrared interferometry data (\sim tenths of AU) is larger than expected for a flat disk model. This discrepancy is discussed in consideration of more complex disk models which include the presence of a hot, inner region or wall in the disk.

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Preprint available at <http://spider.ipac.caltech.edu/staff/rla/>

HST/NICMOS Imaging Survey of the Ophiuchus (Lynds 1688) Cluster

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We present a catalogue of near-infrared photometry of young stars associated with the Ophiuchus molecular cloud, based on observations made with the Hubble Space Telescope NICMOS-3 camera at 1.1 μm and 1.6 μm . Our survey covers 0.02 square degrees centered on the dense molecular cores in Lynds 1688. We detect 165 sources at 1.6 μm and 65 sources at 1.1 μm , within our estimated completeness limits of 21.0 mag and 21.5 mag, respectively. An analysis of the cloud extinction, based on existing molecular line maps, suggests that most of the sources lying within the 40 A_V extinction contour of the cloud are probable cloud members. Approximately half (58/108) of these sources are previously unpublished.

The faint embedded sources revealed by these observations are spatially concentrated in three regions of high stellar space density ($N > 10^4$ stars pc^{-3}). While the spatial distribution of these sources reflects that of the brighter, well-known population of young stars in Ophiuchus, it is distinctly different from the distribution of cool concentrations seen in the submillimeter. Seven new brown dwarf candidates are identified, based on their infrared colors and their projected locations on high column-density regions of the molecular cloud. Eight new candidate binary and five new candidate triple systems, having separations between 0.2 and 10 arcseconds (29 to 1450 AU) are reported. The spatial resolution and sensitivity of these observations reveal five apparent disk/envelope systems seen via scattered light, and four nebulous objects with complex morphologies.

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preprint available at <http://cfa-www.harvard.edu/sfgroup/>

Cometary molecular clouds around RNO 6. On-going star formation near the double cluster h and χ Persei

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We present molecular line observations of the star-forming cloud around RNO 6 along with a newly discovered nearby molecular cloud that we name RNO 6 NW. Both clouds display striking similarities in their cometary structures and overall kinematics. By using ^{13}CO line observations, we estimate that these clouds have similar sizes (~ 4.5 pc) and masses ($\sim 200 M_{\odot}$).

Both molecular clouds RNO 6 and RNO 6 NW are active in star formation. From new high resolution near-IR narrow-band images, we confirm that RNO 6 hosts an embedded IR cluster that includes a Herbig Be star. A conspicuous H_2 filament is found to delineate the dense cometary head of the globule. RNO 6 NW hosts at least two IR sources and a bipolar molecular outflow of ~ 0.9 pc of length and $\sim 0.5 M_{\odot}$ of mass.

We show that the cometary structure of both clouds has been created by the UV radiation from numerous OB stars lying $\sim 1.5^{\circ}$ to the north. Such OB stars are associated with the double cluster h and χ Persei, and are probably members of the Per OB1 association. Thus star formation inside these clouds has been very likely triggered by the Radiation Driven Implosion (RDI) mechanism. From comparison to RDI theoretical models, we find that the similar kinematics and morphology of both clouds is well explained if they are at a re-expansion phase. Triggered sequential star formation also explains the observed spatial distribution of the members of the near-IR cluster inside the RNO 6 cloud, and the morphology of the H_2 filament. We conclude that the RNO 6 and RNO 6 NW clouds are high-mass counterparts to the cometary globules of smaller masses which have been studied up to now. Thus our observations demonstrate that the RDI mechanism can produce, not only low mass stars in small globules, but also intermediate mass stars and clusters in massive clouds.

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<http://www.oan.es/preprints/bachiller.ps.gz>

High-Mass Proto-Stellar Candidates - II: Density structure from dust continuum and CS emission

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We present a detailed 1.2 mm continuum and CS spectral line study of a large sample of 69 massive star forming regions in very early stages of evolution, most of them prior to building up an ultracompact HII region. The continuum data show a zoo of different morphologies and give detailed information on the spatial distributions, the masses, column densities and average densities of the whole sample.

Fitting the radial intensity profiles shows that three parameters are needed to describe the spatial distribution of the sources: constant emission from the center out to a few arcsec radius followed by a first power law intensity distribution which steepens further outside into a second power law distribution. The inner flat region is possibly caused by fragmentation of the large scale cores into smaller sub-sources, whereas the steeper outer power law distributions indicate finite sizes of the cores.

Separating the sources into sub-samples suggests that in the earliest stages prior to the onset of massive star formation the intensity radial distributions are rather flat resembling the structure of intensity peaks in more quiescent molecular clouds. Then in the subsequent collapse and accretion phase the intensity distributions become centrally peaked with steep power law indices. In this evolutionary stage the sources show also the broadest C^{34}S linewidth. During the following phase, when ultracompact HII regions evolve, the intensity power law radial distributions flatten out again. This is probably caused by the ignited massive stars in the center which disrupt the surrounding cores.

The mean inner power law intensity index m_i ($I \sim r^{-m_i}$) is 1.2 corresponding to density indices p ($n \sim r^{-p}$) of 1.6. In total the density distribution of our massive star formations sites seem to be not too different from their low-mass counterparts, but we show that setting tight constraints on the density indices is very difficult and subject to many possible errors.

The local densities we derive from CS calculations are higher (up to one order of magnitude) than the mean densities we find via the mm-continuum. Such inhomogeneous density distribution reflects most likely the ubiquitous phenomenon

of clumping and fragmentation in molecular clouds. Linewidth-mass relations show a departure from virial equilibrium in the stages of strongly collapsing cores.

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Preprints available at: <http://www.mpifr-bonn.mpg.de/staff/beuther/>

The puzzling detection of D₂CO in the molecular cloud L1689N

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We present new observations of the D₂CO emission towards the small cloud L1689N in the ρ Ophiuchus complex. We surveyed five positions, three being a cut across a shock site and two probing the quiescent gas of the molecular cloud. We detected D₂CO emission in the first three positions. The measured [D₂CO]/[H₂CO] is about 3%, whereas it is $\leq 2\%$ in the quiescent gas. We discuss the implications of these new observations, which suggest that the bulk of the D₂CO molecules is stored in grain mantles, and removed from the cold storage by the shock at the interface between the outflowing and quiescent gas. We review the predictions of the published models proposed to explain the observed high deuteration of formaldehyde. They fall in two basic schemes: gas phase and grain surface chemistry. None of the reviewed models is able to account for the observed [D₂CO]/[H₂CO] abundance ratio. A common characteristics shared by the models is apparently that all underestimate the atomic [D]/[H] ratio in the accreting gas.

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<http://www.observ.u-bordeaux.fr/>

A Model for the Thermal Processing of Particles in Solar Nebula Shocks: Application to Cooling Rates of Chondrules

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We present a model for the thermal processing of particles in shock waves typical of the solar nebula. This shock model improves on existing models in that the dissociation and recombination of H₂ and the evaporation of particles are accounted for in their effects on the mass, momentum and energy fluxes. Also, besides thermal exchange with the gas and gas-drag heating, particles can be heated by absorbing the thermal radiation emitted by other particles. The flow of radiation is calculated using the equations of radiative transfer in a slab geometry. We compute the thermal histories of particles as they encounter and pass through the shock.

We apply this shock model to the melting and cooling of chondrules in the solar nebula. We constrain the combinations of shock speed and gas density needed for chondrules to reach melting temperatures, and show that these are consistent with shock waves generated by gravitational instabilities in the protoplanetary disk. After their melting, cooling rates of chondrules in the range 10 – 1000 K hr⁻¹ are naturally reproduced by the shock model. Chondrules are kept warm by the reservoir of hot shocked gas, which cools only as fast as the dust grains and chondrules themselves can radiate away the gas's energy. We predict a positive correlation between the concentration of chondrules in a region and the cooling rates of chondrules in that region. This correlation is supported by the unusually high frequency of (rapidly cooled) barred chondrules among compound chondrules, which must have collided preferentially in regions of high chondrule density. We discuss these and other compelling consistencies between the meteoritic record and the shock wave model of chondrule formation.

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Preprints available at <http://www.ciw.edu/desch/PUB/SHOCKS/DC2002/dc2002.pdf>

A Photometric Catalogue of Southern Emission-Line Stars

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We present a catalogue of previously unpublished optical and infrared photometry for a sample of 162 emission-line objects and shell stars visible from the southern hemisphere. The data were obtained between 1978 and 1997 in the Walraven (*WULBV*), Johnson/Cousins (*UBV(RI)_c*) and ESO and SAAO near-infrared (*JHKLM*) photometric systems. Most of the observed objects are Herbig Ae/Be (HAeBe) stars or HAeBe candidates appearing in the list of HAeBe candidates of Thé et al. (1994), although several B[e] stars, LBVs and T Tauri are also included in our sample. For many of the stars the data presented here are the first photo-electric measurements in the literature. The resulting catalogue consists of 1809 photometric measurements. Optical variability was detected in 66 out of the 116 sources that were observed more than once. 15 out of the 50 stars observed multiple times in the infrared showed variability at 2.2 μm (*K* band).

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Discovery of X-ray emission from the protostellar jet L1551 IRS5 (HH 154)

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We have for the first time detected X-ray emission associated with a protostellar jet, on the jet emanating from the L1551 IRS5 protostar. The IRS5 protostar is hidden behind a very large absorbing column density, making the direct observation of the jet's emission possible. The observed X-ray emission is likely associated with the shock “working surface”, i.e. the interface between the jet and the circumstellar medium. The X-ray luminosity emanating from the jet is, at $L_X \simeq 3 \times 10^{29}$ erg s⁻¹, a significant fraction of the luminosity normally associated with the coronal emission from young stars. The spectrum of the X-ray emission is compatible with thermal emission from a hot plasma, with a temperature of $\simeq 0.5$ MK, fully in line with the temperature expected (on the basis of the jet's velocity) for the shock front produced by the jet hitting the circumstellar medium.

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Intense accretion and mass loss of a very low mass young stellar object

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We present visible and near-infrared photometry and spectroscopy of LS-RCrA 1, a faint, very late-type object (M6.5-M7) seen in the direction of the R Coronae Australis star forming complex. While its emission spectrum shows prominent features of accretion and mass loss typical of young stellar objects, its underlying continuum and photometric properties are puzzling when trying to derive a mass and age based on pre-main sequence evolutionary tracks: the object appears to be far too faint for a young member of the R Coronae Australis complex of its spectral type. We speculate that this may be due to either its evolution along pre-main sequence tracks being substantially altered by the intense accretion, or to a combination of partial blocking and scattering of the light of the object by a nearly edge-on circumstellar disk. The rich emission line spectrum superimposed on the stellar continuum is well explained by an intense accretion process: the H α , CaII infrared triplet, and HeI 6678 lines show equivalent widths typical of very active classical T Tauri stars. The near-infrared observations show anomalously weak spectral features and no significant excess emission in the *K* band, which we tentatively interpret as indicating line filling due to emission in a magnetic accretion funnel flow. At the same time, numerous, strong forbidden optical lines ([OI], [NII] and [SII]) and H $_2$ emission at 2.12 μ m suggest that the object is simultaneously undergoing mass loss, providing another example that shows that mass loss and accretion are closely related processes. Such an intense accretion and mass loss activity is observed for the first time in a young stellar object in the transition region between low mass stars and brown dwarfs, and provides a valuable observational test on the effects of accretion on the evolution of objects with such low masses.

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<http://www.iaa.es/matilde>

The molecular disk surrounding the protostellar binary L1551 IRS5

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The inner three arcminutes surrounding the Class 0/1 binary protostar L1551 IRS5 have been observed using the $J = 1 \rightarrow 0$ transitions of the HCO⁺, H¹³CO⁺, ¹²CO and ¹³CO molecular species. Since the line core of HCO⁺ is self reversed over a substantial part of our map, observations of isotopomers such as H¹³CO⁺ are required in order to estimate the mass of the molecular gas in the immediate vicinity of IRS5. Our observations demonstrate the presence of a large (~ 7000 AU radius) dense, possibly rotating, molecular disk with a mass of a few M_{\odot} oriented perpendicular to the major axis of an extended molecular outflow. The disk is surrounded by an envelope with a radius of ~ 10000 AU that contains two massive (each $\sim 1 M_{\odot}$) clumps. One of these features appears to be kinematically disconnected from both the disk and the molecular outflow.

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<http://astro.esa.int/Pubs/pubs.html>

Mass Loss and Jet Outflow in the Orion Nebula Proplyd LV 2

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We have obtained *HST* STIS high resolution spectra of the Orion proplyd LV 2 in the C III doublet at 1906.68 Å and 1908.73 Å. Images at 6 cm wavelength with MERLIN complement earlier *HST* images at similar spatial resolution.

This object is one of the closest proplyds to θ^1 Ori C, the source of the photoionizing and photoevaporating radiation. Combining the spectra with the HST images and detailed theoretical models has allowed a determination of the mass loss rate as $8.2 \times 10^{-7} M_{\odot} \text{ yr}^{-1} \pm 10\%$. This rate of mass loss is used to address the conundrum of the continued existence of proplyds. Even though they should be photoevaporated in only about 10^5 yrs, there is no evidence for their destruction. It is concluded that the only resolution is that the age of θ^1 Ori C is less than 10^5 yrs.

These spectra and previously unpublished groundbased spectra in [O III] also show the presence of a mono-polar microjet, redshifted by about 100 km s^{-1} with respect to the systemic velocity. This jet is more visible in the 6 cm MERLIN images than in HST images and this image together with the spectra are used to determine the flow parameters for the jet.

Our spectra also include the stand-off shock that lies between LV 2 and θ^1 Ori C. This is the result of the high velocity wind coming from the hot star θ^1 Ori C with the low velocity wind coming from the proplyd. As expected, this shock is at rest with respect to the two objects.

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Preprints available at the anonymous ftp server orion.phy.vanderbilt.edu as file `pub/outgoing/LV2/lv2.ps`

Constraints on Disk Sizes Around Young Intermediate-Mass Stars: Nulling Interferometric Observations of Herbig Ae Objects

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Physical models of circumstellar disks surrounding pre-main sequence stars are currently constrained primarily by the spectral energy distribution (SED) of the system. Here we present first results from a survey of nearby Herbig Ae stars using nulling interferometry. We measure the spatial extent of the mid-IR emission for the stars HD 150193, HD 163296, and HD 179218. The results indicate the size of mid-infrared emission around Herbig Ae stars may be much smaller than current models predict. The observations constrain $\sim 90\%$ of the $10 \mu\text{m}$ flux to be within an approximately 20 AU diameter region, providing significant spatial limits for disk models. These results demonstrate the scientific potential for nulling interferometry to study circumstellar disks with better spatial discernment than is possible with standard mid-infrared imaging.

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Evidence for Accretion: High-Resolution X-ray Spectroscopy of the Classical T Tauri Star TW Hydrae

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We present high resolution X-ray spectra of the X-ray bright classical T Tauri star, TW Hydrae, covering the wavelength range of 1.5-25 Å. The differential emission measure derived from fluxes of temperature-sensitive emission lines shows a plasma with a sharply peaked temperature distribution, peaking at $\log T = 6.5$. Abundance anomalies are apparent, with iron very deficient relative to oxygen, while neon is enhanced relative to oxygen. Density-sensitive line ratios of Ne IX and O VII indicate densities near $\log n_e = 13$. A flare with rapid (~ 1 ks) rise time was detected during our 48 ksec observation; however, based on analysis of the emission-line spectrum during quiescent and flaring states, the derived plasma parameters do not appear strongly time-dependent. The inferred plasma temperature distribution

and densities are consistent with a model in which the bulk of the X-ray emission from TW Hya is generated via mass accretion from its circumstellar disk. Assuming accretion powers the X-ray emission, our results for $\log n_e$ suggest an accretion rate of $\sim 10^{-8} M_\odot \text{ yr}^{-1}$.

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Preprints available on astro-ph (astro-ph/0111049; download paper and figures as separate postscript files)

Active star formation in the large Bok globule CB 34

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We present near-infrared and millimetre observations of the large Bok globule CB 34. Two long parallel trails of H₂ knots are discovered on wide-field images in the 1-0 S(1) 2.12 μ m emission line. These parsec scale H₂ jets extend to the edge of the dark globule where they disappear without the trace of bow shocks. This suggests that the outflows physically extend into a lower density ambient medium where their terminating bows are beyond present detection limits. The two outflows are extremely well collimated and parallel to within 3°. The outflow mechanical luminosity, derived from CO measurements, and the shocked luminosity, estimated from the H₂ emission, are similar, consistent with jet-driven non-evolving outflow structure. The jets appear to originate from the densest cores, as observed in H¹³CO⁺ line emission.

A central concentration of reddened stars and a lower density halo of less reddened stars within the globule are revealed by JHK photometry. Disordered motions are observed in the CO J=2-1 line velocity channel maps and can be driven by the power of the outflows emanating from dense cores. We sketch a picture for the star formation history of the globule in which two star phases have occurred.

A weak diffuse emission halo is detected in the near infrared with colours consistent with either scattered light or a ro-vibrational H₂ cascade. We propose that the halo is produced by ongoing H₂ formation. Cloud evolution and halo H₂ formation timescales are then both a few $\times 10^5$ yr. Thus, we may be witnessing the formation of a molecular cloud out of diffuse atomic gas. This supports a scheme in which this Bok globule has formed independently rather than through dislocation from a nearby molecular cloud.

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Carbon Monoxide Observations of Small Dark Globules: I. Internal Structure

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To probe internal structures of small interstellar clouds we have observed 12 dark globules in the emission of CO isotopes. Full mappings were made in the transition of ¹³CO(J=1→0), while in the ¹²CO(J=1→0) only cross scan observations were done. We have identified 18 sub-condensations from the column density maps of the 12 globules, and derived various physical properties for each of them. The line widths of most sub-condensations show little variation with distance from center. Some of the condensations, however, seem to undergo systematic motions of expansion or contraction. The internal density structure of the sub-condensations closely resembles that of the truncated isothermal gas sphere. The observed line width ΔV of the sub-condensations varies with the size, R , in a power-law fashion $\Delta V \propto R^\beta$ with $\beta = 0.61 \pm 0.11$, which is a somewhat steeper exponent than the one for the cores of GMC's. The result is compared with those from a wide variety of interstellar clouds.

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Interferometric Mapping of Magnetic Fields in Star-forming Regions II. NGC 2024 FIR 5

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We present the first interferometric polarization maps of the NGC 2024 FIR 5 molecular core obtained with the BIMA array at approximately $2''$ resolution. We measure an average position angle of $-60^\circ \pm 6^\circ$ in the main core of FIR 5 and $54^\circ \pm 9^\circ$ in the eastern wing of FIR 5. The morphology of the polarization angles in the main core of FIR 5 suggests that the field lines are parabolic with a symmetry axis approximately parallel to the major axis of the putative disk in FIR 5, which is consistent with the theoretical scenario that the gravitational collapse pulled the field lines into an hour-glass shape. The polarization percentage decreases toward regions with high intensity and close to the center of the core, suggesting that the dust alignment efficiency may decrease at high density. The plane-of-sky field strength can be estimated with the modified Chandrasekhar-Fermi formula, and the small dispersion of the polarization angles in FIR 5 suggests that the magnetic field is strong (≥ 2 mG) and perhaps dominates the turbulent motions in the core.

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Ongoing massive star formation in the bulge of M51

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We present a study of *HST* – *WFPC2* observations of the inner kpc of the interacting galaxy M51 in six bands from 2550 Å to 8140 Å. The images show an oval shaped area (which we call “bulge”) of about 11×16 arcsec or 450×650 pc around the nucleus that is dominated by a smooth “yellow/reddish” background population with overimposed dust lanes. These dust lanes are the inner extensions of the spiral arms. The extinction properties, derived in four fields in and outside dust lanes, is similar to the Galactic extinction law. The reddish stellar population has an intrinsic color of $(B - V)_0 \simeq 1.0$ suggesting an age in excess of 5 Gyrs.

We found 30 bright point-like sources in the bulge of M51 i.e. within 110 to 350 pc from the nucleus. The point sources have $21.4 < V < 24.3$, many of which are blue with $B - V < 0$ and are bright in the UV with $19.8 < m_{2550} < 22.0$. These objects appear to be located in elongated “strings” which follow the general pattern of the dust lanes around the nucleus. The spectral energy distributions of the point-like sources are compared with those predicted for models of clusters or single stars. There are three reasons to conclude that most of these point sources are isolated massive stars (or very small groups of a few isolated massive stars) rather than clusters:

(a) The energy distributions of most objects are best fitted with models of single stars of M_V between -6.1 and -9.1, temperatures between 4000 and 50000 K, and with $4.2 < \log L/L_\odot < 7.2$, and $12 < M_* < 200 M_\odot$.

(b) In the HR diagram the sources follow the Humphreys-Davidson luminosity upper limit for massive stars.

(c) The distribution of the sources in the HR diagram shows a gap in the range of $20\,000 < T_{eff} < 10\,000$ K, which agrees with the rapid crossing of the HRD by stars, but not of clusters.

We have derived upper limits to the total mass of lower mass stars ($M_* < 10 M_\odot$), that could be “hiding” within the point sources. For the “bluest” sources the upper limit is only a few hundred M_\odot .

We conclude that the formation of massive stars outside clusters (or in very low mass clusters) is occurring in the bulge of M51.

The estimated star formation rate in the bulge of M51 is 1 to $2 \times 10^{-3} M_\odot \text{ yr}^{-1}$, depending on the adopted IMF. With the observed total amount of gas in the bulge, $\sim 4 \times 10^5 M_\odot$, and the observed normal gas to dust ratio of ~ 150 , this star formation rate could be sustained for about 2 to 4×10^8 years. This suggests that the ongoing massive star formation in the bulge of M51 is fed/triggered by the interaction with its companion about 4×10^8 years ago. The star formation in the bulge of M51 is compared with that in bulges of other spirals.

Theoretical predictions of star formation suggest that isolated massive stars might be formed in clouds in which H_2 , [OI] $63 \mu\text{m}$ and [CII] $158 \mu\text{m}$ are the dominant coolants. This is expected to occur in regions of rather low optical depth, $A_V \leq 1$, with a hot source that can dissociate the CO molecules. These conditions are met in the bulge of M51, where the extinction is low and where CO can be destroyed by the radiation from the bright nuclear starburst cluster in the center. The mode of formation of massive stars in the bulge of M51 may resemble the star formation in the early Universe, when the CO and dust contents were low due to the low metallicity.

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A young protoplanetary disk in the Bok globule CB 26?

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We present sub-arcsecond resolution millimeter-wave images of a circumstellar disk in the Bok globule CB 26. The presence of an edge-on disk is confirmed by the dust continuum morphology and the velocity field of ^{13}CO emission, which displays a Keplerian rotation pattern about an axis perpendicular to the long axis of the dust emission. We deduce a mass $\sim 0.3 M_\odot$ for the obscured central star. The disk is optically thick at mm wavelengths inside 120 AU, has a symmetric 20° warp beyond 120 AU, an outer radius of ~ 200 AU, and a mass of at least $0.1 M_\odot$. We suggest that the CB 26 system is in an intermediate stage between deeply embedded protostellar accretion disks and the more evolved, perhaps protoplanetary, disks around T Tauri stars.

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Imaging and spectroscopic studies of Haro 6-19 (HH319)

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We performed morphological and spectro-imaging investigations of the little-studied HH object Haro 6-19 (HH319). Besides the main object, two other small HH knots were found. The images of the object in various spectral lines and maps of radial velocity and electronic density are presented. Either of the T Tauri stars FY and FZ Tau is suggested as the possible exciting source. The spatial distribution of the density and radial velocity in the object, combined with other evidences, shows that HH319 could be a shocked cloudlet. In many aspects HH319 is similar to HH29 in L1551.

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NGC 2362: a Template for Early Stellar Evolution

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We present UBVRI photometry for the young open cluster NGC 2362. From analysis of the appropriate color-color and color-magnitude diagrams we derive the fundamental parameters of the NGC 2362 cluster to be: age = 5_{-2}^{+1} Myr, distance = 1480 pc, $E(B - V) = 0.10$ mag. The cluster age was independently determined for both high mass ($2.1 - 36M_{\odot}$) and low mass ($0.7 - 1.2M_{\odot}$) stars with excellent agreement between the ages derived using post-main sequence (Girardi et al. 2000, A&AS, 141, 371) and pre-main sequence (Baraffe et al. 1998, A&A, 337, 403) evolutionary tracks for the high and low mass stars respectively. Analysis of this cluster's color-magnitude diagram reveals a well defined pre-main sequence (covering $\Delta V \sim 9$ magnitudes in V and extending from early A stars to near the hydrogen burning limit) which makes this cluster an ideal laboratory for pre-main sequence evolution studies.

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Chromospheric activity, lithium and radial velocities of single late-type stars possible members of young moving groups

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We present here high resolution echelle spectra taken during three observing runs of 14 single late-type stars identified in our previous studies (Montes et al. 2001b, hereafter Paper I) as possible members of different young stellar kinematic groups (Local Association (20 - 150 Myr), Ursa Major group (300 Myr), Hyades supercluster (600 Myr), and IC 2391 supercluster (35 Myr)). Radial velocities have been determined by cross correlation with radial velocity standard stars and used together with precise measurements of proper motions and parallaxes taken from Hipparcos and Tycho-2 Catalogues, to calculate Galactic space motions (U, V, W) and to apply Eggen's kinematic criteria. The chromospheric activity level of these stars have been analysed using the information provided for several optical spectroscopic features (from the Ca II H & K to Ca II IRT lines) that are formed at different heights in the chromosphere. The Li I $\lambda 6707.8$ Å line equivalent width (EW) has been determined and compared in the $EW(\text{Li I})$ versus spectral type diagram with the $EW(\text{Li I})$ of stars members of well-known young open clusters of different ages, in order to obtain an age estimation. All these data allow us to analyse in more detail the membership of these stars in the different young stellar kinematic groups. Using both, kinematic and spectroscopic criteria we have confirmed PW And, V368 Cep, V383 Lac, EP Eri, DX Leo, HD 77407, and EK Dra as members of the Local Association and V834 Tau, π^1 UMa, and GJ 503.2 as members of the Ursa Major group. A clear rotation-activity dependence has been found in these stars.

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<http://www.ucm.es/info/Astrof/MS1718.ps.gz>, see also: http://www.ucm.es/info/Astrof/skg/skg_catalogue.html

On the frequency of the CS (J:2→1) and (J:5→4) transitions

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While conducting high signal-to-noise ratio (SNR) observations of multiple transitions and different isotopomers of CS,

SO and CO towards L183 (also known as L134N), we found that the CS (J:2→1) line frequency established by Kuiper et al. (1996) during observations towards L1498 was in disagreement with our observations. We have consequently repeated their observations towards that object, but in a slightly different manner by observing simultaneously the CS (J:2→1) line at 98 GHz and the CCS ($J_N:8_7 \rightarrow 7_6$) line at 94 GHz with the same telescope and the same receivers therefore eliminating the possibility of errors associated with either software or hardware. We found that our L183 data was best described with the standard frequency of 97980.95 MHz. We also found a real difference in the velocity position of the CS and CCS peaks in L1498, but one only half that reported by Kuiper et al. (1996). Most importantly, we have established that the L1498 cloud is not well-suited for setting the CS (J:2→1) frequency despite the exceptional narrowness of the lines. The CS (J:2→1) line shape is far from Gaussian and suffers from strong effects, due either to large scale movements (infall and/or rotation), or to self-absorption, or both. These results and other works (Lemme et al. 1995, Lee et al. 1999) have convinced us that these observations are consistent with the standard CS (J:2→1) line frequency. We also checked the C³⁴S (J:2→1) and the CS (J:5→4) transitions and found a major discrepancy for the latter with the JPL catalogue. Finally, CS transitions have been recently re-measured in the laboratory by Gottlieb et al. (2001) with high precision and are found to be consistent with our interpretation.

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A High Angular Resolution Multiplicity Survey of the Open Clusters α Persei and Praesepe

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Two hundred and forty-two members of the Praesepe and α Persei clusters have been surveyed with high angular resolution 2.2 m speckle imaging on the IRTF 3-m, the Hale 5-m, and the Keck 10-m, along with direct imaging using the near-infrared camera (NICMOS) aboard the Hubble Space Telescope (HST). The observed stars range in spectral type from B ($5 M_\odot$) to early-M ($0.5 M_\odot$), with the majority of the targets more massive than $0.8 M_\odot$. from $0''.053$ to $7''.28$; 28 of the systems are new detections and there are 9 candidate substellar companions. The results of the survey are used to test binary star formation and evolution scenarios and to investigate the effects of companion stars on X-ray emission and stellar rotation. The main results are:

* Over the projected separation range of 26-581 AU and magnitude differences of $\Delta K \leq 4.0$ mag (comparable to mass ratios, $q=m_{sec}/m_{prim} \geq 0.25$), the companion star fraction (CSF) for α Persei is 0.09 ± 0.03 and for Praesepe is 0.10 ± 0.03 . This fraction is consistent with the field G-dwarf value, implying that there is not a systematic decline in multiplicity with age at these separations on timescales of a few $\times 10^7$ yrs. The combination of previous spectroscopic work and the current cluster survey results in a cluster binary separation distribution that peaks at $4_{-1.5}^{+1}$ AU, a significantly smaller value than the peaks of both the field G-dwarf and the nearby T Tauri distributions. If the field G-dwarf distribution represents a superposition of distributions from the populations that contributed to the field, then the data implies that $\sim 30\%$ of field binaries formed in denser regions.

* An exploration of the binary star properties reveals a cluster CSF that increases with decreasing target mass and a cluster mass ratio distribution that rises more sharply for higher mass stars, but is independent of binary separation. These observational trends are consistent with several models of capture in small clusters and simulations of accretion following fragmentation in a cluster environment. Other types of capture and fragmentation are either inconsistent with these data or currently lack testable predictions.

* Among the cluster A stars, there is a higher fraction of binaries in the subset with X-ray detections, consistent with the hypothesis that lower mass companions are the true source of X-ray emission.

* Finally, in the younger cluster α Persei, the rotational velocities for solar-type binaries with separations less than 60 AU are significantly higher than that of wider rotational evolution of young stars.

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ISO spectroscopy of compact HII regions in the Galaxy : I. The catalogue

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Infrared spectra between 2.3 and 196 μm were taken towards a sample of 45 compact HII regions using the two spectrometers (SWS and LWS) on board ISO. The primary goal is to determine the distribution of element abundances in the Galaxy, although there are also many other uses of this database. The spectra contain a wealth of information on the ionized gas and the associated photodissociation regions through the atomic fine-structure lines and on the dust properties via the dust emission bands and the continuum. Significant variations are found from source to source in both spectral shape and content. The sample of HII regions spans a wide range in galactocentric distance (from 0 to 22 kpc) enabling to investigate the variations of the nebular properties across the Galactic plane. The observations and the data reduction are described in detail in the present paper. The ISO spectral catalogue of compact HII regions contains the combined SWS-LWS spectra for each of the sources, the fluxes of the atomic fine-structure lines and hydrogen recombination lines, and an inventory of the spectra in terms of molecular lines, dust and ice bands.

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Detailed Structure of Low-Density Molecular Gas in High-Latitude Clouds

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Extensive strip-scan observations of three high-latitude clouds — MBM 32, MBM 54, and MBM 55 — were carried out in $^{12}\text{CO } J = 1-0$ emission with an angular resolution of $15''$, or 0.0072 pc (1500 AU) at 100 pc . We resolved clumps with sizes from $\sim 0.2 \text{ pc}$ down to $\sim 0.02 \text{ pc}$. Most of them have low gas density ($< 10^2 \text{ cm}^{-3}$) and sizes significantly smaller than their corresponding Jeans lengths. Some of them are well isolated from the rest of the molecular components, suggesting their (quasi-) stable dynamical state. They provide a clear case for structure formation not caused by gravitational contraction, and are most likely formed through thermal instability in interstellar shocks.

We unexpectedly discovered in the position-velocity diagrams a number of localized velocity shifts. Their typical size is 0.05 pc and some of them exhibit a velocity gradient of $\sim 40 \text{ km s}^{-1} \text{ pc}^{-1}$, which is among the largest ever observed in non-star-forming clouds. None of them have young stellar objects in their vicinity. Contraction of shock-compressed gas may produce rapidly rotating/contracting but apparently unbound clumps. These features may provide more evidence for structure formation through thermal instability of shocked gas.

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A Detailed Study of G173.58+2.45: an Intermediate-Mass Star Forming Region

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The G173.58+2.45 outflow was imaged in CO line emission, millimeter and centimeter continuum emission, and near-infrared emission. The observations provide evidence that the outflow is produced by at least two young stellar objects (spectral types late B to mid A) located in a cluster of near-infrared sources near the center of the molecular outflow. The combined mass outflow rate of $1 \times 10^{-4} M_{\odot} \text{ yr}^{-1}$ provides an upper limit on the luminosity of the young stellar objects powering the outflow of $50 L_{\odot}$ (spectral type later than B7) which is consistent with the near-infrared data. There is no indication of a well-collimated jet either on large or small scales that could power the outflow. We conclude that G173.58+2.45 is an excellent example of clustered, intermediate-mass star formation at an age of roughly 10^5 years. The near-infrared observations also suggest that the cluster contains at least two mid to early B stars, neither of which appear to be in an outflow stage. Our improved understanding of the G173.58+2.45 young star cluster contrasts sharply with previous conclusions, based on low-resolution images, that a single outflow with relatively simple morphology was powered by a jet from an early B star. This analysis illustrates that caution should be exercised before low-resolution images are used to infer conditions in massive star forming regions and the accretion-outflow mechanism associated with massive stars.

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High-Mass Proto-Stellar Candidates - I : The Sample and Initial Results

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We describe a systematic program aimed at identifying and characterizing candidate high-mass proto-stellar objects (HMPOs). Our candidate sample consists of 69 objects selected by criteria based on those established by Ramesh & Sridharan (1997) using far-infrared, radio-continuum and molecular line data. Infrared-Astronomical-Satellite (*IRAS*) and Midcourse-Space-Experiment (MSX) data were used to study the larger scale environments of the candidate sources and to determine their total luminosities and dust temperatures.

To derive the physical and chemical properties of our target regions, we observed continuum and spectral line radiation at millimeter and radio wavelengths. We imaged the free-free and dust continuum emission at wavelengths of 3.6 cm and 1.2 mm, respectively, searched for H₂O and CH₃OH maser emission and observed the CO $J = 2 \rightarrow 1$ and several NH₃ lines toward all sources in our sample. Other molecular tracers were observed in a subsample.

While dust continuum emission was detected in all sources, most of them show only weak or no emission at 3.6 cm. Where detected, the cm emission is frequently found to be offset from the mm emission, indicating that the free-free and dust emissions arise from different subsources possibly belonging to the same (proto)cluster. A comparison of the luminosities derived from the cm emission with bolometric luminosities calculated from the *IRAS* far-infrared fluxes shows that the cm emission very likely traces the most massive source, whereas the whole cluster contributes to the far-infrared luminosity. Estimates of the accretion luminosity indicate that a significant fraction of the bolometric luminosity is still due to accretion processes. The earliest stages of HMPO evolution we seek to identify are represented by dust cores without radio emission.

Line wings due to outflow activity are nearly omnipresent in the CO observations, and the molecular line data indicate the presence of hot cores for several sources, where the abundances of various molecular species are elevated due to evaporation of icy grain mantles. Kinetic gas temperatures of 40 sources are derived from NH₃ (1,1) and (2,2) data, and we compare the results with the dust temperatures obtained from the *IRAS* data.

Comparing the amount of dust, and hence the gas, associated with the HMPOs and with ultracompact HII regions (UCHIIs) we find that the two types of sources are clearly separated in mass-luminosity diagrams: for the same dust masses the UCHII regions have higher bolometric luminosities than HMPOs. We suggest that this is an evolutionary trend with the HMPOs being younger and reprocessing less (stellar) radiation in the IR than the more evolved UCHII regions.

These results indicate that a substantial fraction of our sample harbors HMPOs in a pre-UCHII region phase, the earliest known stage in the high-mass star formation process.

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[FeII] 1.257 μm and HeI 1.083 μm emission in the central region of the Orion Nebula: HII region, HH flows, jets, and proplyds

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The [FeII] 1.257 μm and HeI 1.083 μm emission lines were observed in the central 6'×8' region of the Orion Nebula, and their excitation in the photoionized HII region, HH flows, jets, and proplyds is investigated. Observations were carried out using an imaging Fabry-Perot spectrometer MUSE, which provides a 4'×4' FOV at the NAOJ 1.5-m infrared telescope and a spectral resolution $\lambda/\delta\lambda$ of ~ 2000 at the observed wavelengths. The [FeII] images exhibit (1) filamentary structures and diffuse emission, which presumably arise from ionization fronts of the photoionized HII region, and (2) a number of knots, some of which are newly identified. Centroidal velocities in most of the knots are negative relative to those in the ionization fronts by up to -60 km s^{-1} , and observed line profiles in the bright knots exhibit blue-shifted wings, agreeing with bow shock models. The HeI 1.083 μm emission in the observed region is dominated by the photoionized HII region, and its distribution reflects the complicated nature of the excitation. The HeI images also contain blue-shifted emission from several HH flows and jets, and red-shifted emission associated with proplyds.

Our results for the shocks suggest that the [FeII] 1.257 μm and HeI 1.083 μm emission reflects the ionization of the pre-shock gas: the [FeII] 1.257 μm emission is prominent in shocks propagating in molecular/atomic gas, while the HeI 1.083 μm is prominent in shocks in the photoionized HII region. Different line excitation in these shocks can be explained by the following physical properties and processes: (1) difference of the excitation energies from the ground state (1 eV and 20 eV for the [FeII] and HeI lines, respectively), (2) resonance scattering and collisional excitation from the metastable state, enhancing the HeI 1.083 μm line in shocks in the photoionized HII region, (3) a large photoionization cross section of Fe^+ , causing the absence of the [FeII] emission in the same shocks, and possibly (4) charge exchange reactions of Fe, which could enhance the [FeII] emission in neutral gas.

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First spectroscopically confirmed discovery of an extragalactic T Tauri star

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We report the first spectroscopic discovery of an extragalactic bona-fide T Tauri star. The object, LTS J054427-692659, is a low-mass, late-type star located within the LMC dark cloud Hodge II 139. It shows $\text{H}\alpha$ emission with an equivalent width of 78 Å, in line with galactic T Tauri stars, but in excess of any main-sequence dwarf star. The only known plausible interpretation of LTS J054427-692659 is a LMC T Tauri star.

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A Disk/Jet System toward the High-mass Young Star in AFGL 5142

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We present observational studies of a high-mass star forming region AFGL 5142 in the NH_3 (J,K)=(1,1), (2,2), (3,3) and (4,4) inversion transitions. We discover a compact structure of $1''$ (or 1800AU) in NH_3 emission toward the position of a high-mass young star. The star, with a spectral type of B2 if it is at the zero-age main-sequence, excites a weak centimeter continuum source and drives a well collimated SiO jet. The compact NH_3 structure, with a temperature of 70 K, gives rise to a broad NH_3 line emission of 6.4 km s^{-1} (full width at half maximum). The small size of the NH_3 feature, broad line emission and the association with a SiO jet indicate that the object is most likely an unresolved rotating disk. The compact disk is embedded in a flattened core of gas temperatures of about 20 K. The extended core delineates an 'X' shape with the SiO jet located in the void of the dense and cold NH_3 gas. A faint component of NH_3 emission can be identified, especially in the highly excited NH_3 (3,3) and (4,4) lines, tracing the SiO jet. This component, arising from hot gas of about 170 K, is likely heated by shocks in the outflow. The coincidence of a disk and a jet with the radio continuum source toward AFGL 5142 indicates that this high-mass star may have formed via a disk mediated accretion process.

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Preprint: <http://cfa-www.harvard.edu/~qzhang>.

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).

Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter.

The Star Formation Newsletter is available on the World Wide Web at <http://casa.colorado.edu/reipurth> or at <http://www.eso.org/gen-fac/pubs/starform/>.

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 Jobs

POSTDOCTORAL FELLOWSHIPS IN STAR FORMATION

Leiden Observatory, The Netherlands

Two postdoctoral fellowships will be available at Leiden Observatory within the Molecular Astrophysics group. They form part of a long-term program to study the physical and chemical evolution of star- and planet-forming regions through a combination of theory and observations at submillimeter and infrared wavelengths. One position will focus on infrared spectroscopy to be carried out within the context of an approved SIRTf legacy program. The second position will concentrate on submillimeter single-dish and interferometry data and radiative transfer methods. The appointments are initially for two years, with the possibility of renewal for a third year. They can start anytime in 2002. Candidates with an observational or theoretical background in star formation, circumstellar disks and/or astrochemistry are encouraged to apply.

Applicants should send a curriculum vitae, publication list, and a statement of research interests, and arrange for three letters of recommendation to be sent to Professor E.F. van Dishoeck Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands; Fax: +31-71-5275819; e-mail: ewine@strw.leidenuniv.nl; url: www.strw.leidenuniv.nl/~ewine/. The closing date for applications and all letters of recommendation is December 15, 2001.

Postdoctoral Positions in Star Formation and Computational Astrophysics

The ASIAA (<http://www.asiaa.sinica.edu.tw>), located in the campus of National Taiwan University in Taipei, is an institute of the Academia Sinica, the national research organization in Taiwan. The ASIAA is an internationally oriented institute where English is the working language. Members of ASIAA are conducting vigorous research programs addressing questions in the forefront of astronomy and astrophysics. Current research areas include star formation; nuclear astrophysics; galactic and extra-galactic astronomy; Cosmology; computational fluid dynamics (CFD) and magnetohydrodynamics (MHD). The ASIAA has strong international collaborations and interdisciplinary exchanges among scholars worldwide.

We invite applications for postdoctoral positions in the general areas of star formation and computational astrophysics, to start in summer and fall of 2002. Candidates with strong research credentials should submit a curriculum vitae, a statement of research and interests, a publication list, and three letters of recommendation to: Prof. K. Y. Lo, Box 23-141, Taipei 106, Taiwan; by Email: asiaa@asiaa.sinica.edu.tw, Subject line: Star Formation, by December 20, 2001.

We will also fill two immediate openings with the CFD-MHD group to start as early as January 01, 2002. One of the positions will be specialized in graphics and visualization. PhD candidates with strong computational and programming experiences should submit above application material to: asiaa@asiaa.sinica.edu.tw, and subject line: CFD-MHD by December 1, 2001. Inquiries about these two positions should be directed to Dr. Chi Yuan (yuan@asiaa.sinica.edu.tw) or Dr. Hsien Shang (shang@asiaa.sinica.edu.tw).

Postdoctoral and PhD positions on: Massive star forming regions and starburst galaxies

E-mail contact: schaerer@ast.obs-mip.fr

Postdoctoral position

The Geneva Observatory in Geneva, Switzerland, announces the availability of a research position at the postdoctoral level, open to applicants of all nationalities.

The successful candidate will work on a project aimed at studying the stellar populations and the interstellar medium of massive star forming regions from the local Universe to high redshift, involving both multi-wavelength observations and theoretical modeling. The successful applicant will in particular have access to ground-based observational data covering the optical to mid-IR (including ESO/VLT data), and state-of-the-art modeling tools. He/she will mostly work in collaboration with Prof. Daniel Schaerer in Geneva.

The Geneva Observatory carries out observational, interpretative and theoretical research in fields including stellar evolution, stellar physics, galaxy evolution and dynamics, high energy astrophysics, and extra-solar planets.

The initial appointment will be for one to two years starting in fall 2002 (1 october 2002 or later). It is renewable.

Qualified candidates are encouraged to send their application including a CV, description of research experience and interests, and contact information of three references preferably via email to Daniel Schaerer (schaerer@ast.obs-mip.fr), Laboratoire d'Astrophysique, 14, Av. E. Belin, F-31400 Toulouse, France.

All applications received by January 4, 2002 will receive full consideration. Informal enquiries with Daniel Schaerer (schaerer@ast.obs-mip.fr) are welcome.

Related information also available from the URL:

<http://webast.ast.obs-mip.fr/people/schaerer/>

PhD student position

One or two PhD student positions at the Geneva Observatory are open on topics related to "Massive Star Forming Regions from the local Universe to high redshift", i.e. objects ranging from giant HII regions and starburst galaxies to the first galaxies (so-called Population III objects). The student will work with Prof. D. Schaerer and collaborators of the group. Observational and/or theoretical subjects are proposed.

Start of PhD: fall 2002 (1 october 2002 or later)

For more details on these positions, detailed topics, and other information, contact Daniel Schaerer (schaerer@ast.obs-mip.fr).

Related information also available from the URL:

<http://webast.ast.obs-mip.fr/people/schaerer/>

New Books

Young Stars Near Earth: Progress and Prospects

Editors: Ray Jayawardhana and Thomas P. Greene

These are the proceedings of the first scientific meeting dedicated to the topic of young stellar systems in the solar neighborhood, held at the NASA Ames Research Center in Mountain View, California on March 28-30, 2001. The workshop was a forum to present the latest findings, debate unresolved issues, consider implications for local star formation, and discuss prospects for future missions and facilities. Due to the rapid growth of this research area in recent years, many of the results presented here are new. Among the topics covered are:

- Identification of nearby young associations
- Kinematics, astrometry, distances and age estimates
- Stellar characteristics, variability, star spots, and X-ray emission
- Local interstellar medium and formation scenarios
- Disk evolution and planet formation
- Searches for brown dwarf and planetary companions
- Prospects for the future (KI, VLTI, FAME, SIRTf, SOFIA, ALMA, SIM)

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