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Abstracts of recently accepted papers

Profiles of Strong Permitted Lines in Classical T Tauri Stars

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We present a spectral analysis of 30 T Tauri stars observed with the Hamilton echelle spectrograph over more than a decade. One goal is to test magnetospheric accretion model predictions. Observational evidence previously published supporting the model, such as emission line asymmetry and a high frequency of redshifted absorption components, are considered. We also discuss the relation between different line forming regions and search for good accretion rate indicators.

In this work we confirm several important points of the models, such as the correlation between accretion and outflow, broad emission components that are mostly central or slightly blueshifted and only the occasional presence of redshifted absorption. We also show, however, that the broad emission components supposedly formed in the magnetospheric accretion flow only partially support the models. Unlike the predictions, they are sometimes redshifted, and are mostly found to be symmetric. The published theoretical profiles do not have a strong resemblance to our observed ones. We emphasize the need for accretion models to include a strong turbulent component before their profiles will match the observations. The effects of rotation, and the outflow components, will also be needed to complete the picture.

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Predicting the Properties of Binary Stellar Systems: The Evolution of Accreting Protobinary Systems

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We investigate the formation of binary stellar systems. We consider a model where a ‘seed’ protobinary system forms, via fragmentation, within a collapsing molecular cloud core and evolves to its final mass by accreting material from an infalling gaseous envelope. This accretion alters the mass ratio and orbit of the binary, and is largely responsible for forming the circumstellar and/or circumbinary discs.

Given this model for binary formation, we predict the properties of binary systems and how they depend on the initial conditions within the molecular cloud core. We predict that there should be a continuous trend such that closer binaries are more likely to have equal mass components and are more likely to have circumbinary discs than wider systems. Comparing our results to observations, we find that the observed mass-ratio distributions of binaries and the frequency of circumbinary discs as a function of separation are most easily reproduced if the progenitor molecular cloud cores have radial density profiles between uniform and $1/r$ (e.g. Gaussian) with near uniform-rotation. This is

in good agreement with the observed properties of pre-stellar cores. Conversely, we find that the observed properties of binaries cannot be reproduced if the cloud cores are in solid-body rotation and have initial density profiles which are strongly centrally condensed. Finally, in agreement with the radial-velocity searches for extra-solar planets, we find that it is very difficult to form a brown dwarf companion to a solar-type star with a separation < 10 AU, but that the frequency of brown dwarf companions should increase with larger separations or lower mass primaries.

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The Stellar Content of Obscured Galactic Giant H II Regions: II. W42

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We present near infrared J, H, and K images and K-band spectroscopy in the giant HII region W42. A massive star cluster is revealed; the color-color plot and K-band spectroscopic morphology of two of the brighter objects suggest the presence of young stellar objects. The spectrum of the bright central star is similar to unobscured stars with MK spectral types of O5–O6.5. If this star is on the zero age main sequence, then the derived spectrophotometric distance is considerably smaller than previous estimates. The Lyman continuum luminosity of the cluster is a few times that of the Trapezium. The slope of the K-band luminosity function is similar to that for the Trapezium cluster and significantly steeper than that for the massive

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The luminosity function of galactic ultra-compact H II regions and the IMF for massive stars

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The population of newly formed massive stars, while still embedded in their parent molecular clouds, is studied on the galactic disk scale. We analyse the luminosity function of IRAS point-like sources, with far-infrared (FIR) colours of ultra-compact H II regions, that have been detected in the CS(2–1) line - a tracer of high density molecular gas. The FIR luminosities of 555 massive star forming regions (MSFRs), 413 of which lie within the solar circle, are inferred from their fluxes in the four IRAS bands and from their kinematic distances, derived using the CS(2–1) velocity profiles. The luminosity function (LF) for the UCHII region candidates shows a peak well above the completeness limit, and is different within and outside the solar circle (96% confidence level). While within the solar circle the LF has a maximum for $2 \cdot 10^5 L_{\odot}$, outside the solar circle the maximum is at $5 \cdot 10^4 L_{\odot}$. We model the LF using three free parameters: $-\alpha$, the exponent for the initial mass function (IMF) expressed in $\log(M/M_{\odot})$; $-\beta$, the exponent for a power law distribution in N^* , the number of stars per MSFR; and N_{\max}^* , an upper limit for N^* . While α has a value of ~ 2.0 throughout the Galaxy, β changes from ~ 0.5 inside the solar circle to ~ 0.7 outside, with a maximum for the number of stars per MSFR of ~ 650 and ~ 450 (with $1 \leq M/M_{\odot} \leq 120$). While the IMF appears not to vary, the average number of stars per MSFR within the solar circle is higher than for the outer Galaxy.

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The cooling of astrophysical media by HD

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The results of recent quantum mechanical calculations of cross sections for rotational transitions within the vibrational ground state of HD, are used to evaluate the rate of radiative energy loss from gas containing HD, in addition to H, He and H₂. The cooling function for HD (i.e. the rate of cooling per HD molecule) is evaluated in steady state on a grid of values of the relevant parameters of the gas, namely, the gas density and temperature, the atomic to molecular hydrogen abundance ratio, and the ortho:para-H₂ density ratio. The corresponding cooling function for H₂, previously computed by Le Bourlot et al. (1999, MNRAS, 305, 802), is slightly revised to take account of transitions induced by collisions with ground state ortho-H₂ ($J = 1$). The cooling functions and the data required for their calculation are available from <http://ccp7.dur.ac.uk/>. We then make a study of the rate of cooling of the primordial gas through collisions with H₂ and HD molecules. In this case, radiative transitions induced by the cosmic background radiation field and, in the case of H₂, collisional transitions induced by H⁺ ions should additionally be included.

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ISO SWS-LWS observations of the prototypical reflection nebula NGC 7023

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We present SWS and LWS ISO observations towards a strip across the photodissociation region (PDR) in the reflection nebula NGC 7023. SWS02 and LWS01 spectra have been taken towards the star and the brightest infrared filaments located NW and SW from the star (hereafter NW and SW PDRs). In addition, SWS02 spectra have been taken towards two intermediate positions (NW1 and SW1). This has provided important information about the extent and spatial distribution of the warm H₂ and of the atomic species in this prototypical reflection nebula.

Strong emission of the [SiII] 34.8 μ m line is detected towards the star. While all the PDR tracers (the [CII] 157.7 μ m, [OI] 63.2 and 145.6 μ m, [HI] 21cm and the H₂ rotational lines) present a ring-like morphology with the peaks toward the NW and SW PDRs and a minimum around the star, the SiII emission is filling the hole of this ring with the peak towards the star. This morphology can only be explained if the SiII emission arise in the lowest extinction layers of the PDR ($A_v < 2$ mag) and the HII region. At least 20% – 30% of the Si must be in gas phase in these layers. For $A_v \geq 2$ mag, the Si is mainly in solid form (δ Si = -1.3).

The NW and SW PDRs have very similar excitation conditions, high density filaments ($n \sim 10^6$ cm⁻³) immersed in a more diffuse interfilament medium ($n \sim 10^4$ cm⁻³). In both, the NW and SW PDRs, the intensities of the H₂ rotational lines can only be fitted by assuming an ortho-to-para-H₂ ratio lower than 3 in gas with rotation temperatures from 400 to 700 K. Therefore, there is a non-equilibrium OTP ratio in the region. Furthermore, the comparison between the OTP ratio derived from H₂ vibrational lines and the pure H₂ rotational lines, shows that the OTP ratio increases from ~ 1.5 to 3 across the photodissociation region with larger values in the less shielded gas ($A_v < 0.7$ mag). This behavior is interpreted as a consequence of an advancing photodissociation front.

We have not detected the OH, CH and CH₂ lines towards the observed positions. This is consistent with the weakness of these lines in other sources and can be explained as a consequence of the small beam filling factor of the dense gas in the LWS aperture. The CO J=17 \rightarrow 16 line has been tentatively detected towards the star.

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<http://www.oan.es/preprints>

Ammonia observations of the nearby molecular cloud MBM 12

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We present NH₃(1,1) and (2,2) observations of MBM 12, the closest known molecular cloud (65 pc distance), aimed to find evidence for on-going star formation processes. No local temperature (with a T_{rot} upper limit of 12 K) nor linewidth enhancement is found, which suggests that the area of the cloud we mapped ($\sim 15'$ size) is not currently forming stars. Therefore, this close “starless” molecular gas region is an ideal laboratory to study the physical conditions preceding new star formation.

A radio continuum source was found in Very Large Array archive data, close but outside the NH₃ emission. This source is likely to be a background object.

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HC₃N and the ages of dense cores

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Fractional abundances of HC₃N and a number of other species are presented for dense core models based on a variety of different assumptions. The highest calculated values of the HC₃N fractional abundances arise in static models where many species striking grain surfaces are processed in hydrogenation reactions leading to the rapid injection of saturated species into the gas phase; in these models the HC₃N is most abundant well before chemical equilibrium is reached. The effects of the various parameters considered are strongly coupled and lead to markedly differing ratios of the HC₃N abundance relative to abundances of other species including H₂CO, C₃H and C₄H. Although none of these models is specific to any particular astronomical object, we briefly compare our results with abundances observed in TMC-1. We conclude that the molecular abundances observed in TMC-1 can be accounted for on the basis of models of the type discussed here, and that - although this much-studied object has unusually high molecular abundances - it is not chemically anomalous compared to other dense cores.

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Dust in the 55 Cancri planetary system

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The presence of debris disks around ~ 1 -Gyr-old main sequence stars suggests that an appreciable amount of dust may persist even in mature planetary systems. Here we report the detection of dust emission from 55 Cancri, a star with one, or possibly two, planetary companions detected through radial velocity measurements. Our observations at $850\mu\text{m}$ and $450\mu\text{m}$ imply a dust mass of 0.0008-0.005 Earth masses, somewhat higher than that in the the Kuiper Belt of our solar system. The estimated temperature of the dust grains and a simple model fit both indicate a central disk hole of at least 10 AU in radius. Thus, the region where the planets are detected is likely to be significantly depleted of dust. Our results suggest that far-infrared and sub-millimeter observations are powerful tools for probing the outer regions of extrasolar planetary systems.

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Rings in the Planetesimal Disk of β Pic

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The nearby main sequence star β Pic is surrounded by an edge-on disk of dust produced by the collisional erosion of larger planetesimals. Here we report the discovery of substructure within the northeast extension of the disk midplane that may represent an asymmetric ring system around β Pic. We present a dynamical model showing that a close stellar flyby with a quiescent disk of planetesimals can create such rings, along with previously unexplained disk asymmetries. Thus we infer that β Pic's planetesimal disk was highly disrupted by a stellar encounter in the last hundred thousand years.

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On the Formation of Stellar Clusters: Gaussian Cloud Conditions I

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The isothermal dynamical evolution of a clumpy molecular cloud region and its fragmentation into a protostellar cluster is investigated numerically. The initial density distributions are generated from different realizations of a Gaussian random field with power spectrum $P(k) \propto k^{-2}$. During the evolution of the system, the one-point probability distribution functions (pdf) of the gas density and of the line-of-sight velocity centroids develop considerable distortions away from the initial Gaussian behavior. The density pdf can be best described by power-law distributions, whereas the velocity pdf exhibits extended tails. As a result of the interplay between gas pressure and gravitational forces, a quasi-equilibrium clump mass spectrum emerges with a power-law distribution $dN/dM \propto M^{-1.5}$. Being part of a complex network of filaments, individual clumps are elongated, centrally condensed objects with 2:1 to 4:1 axis ratios with outer r^{-2} density distributions.

Dense, Jeans-unstable gas clumps collapse and form protostellar cores which evolve through competitive accretion and N -body interactions with other cores. In contrast to the clumps, the core mass spectrum is best described by a log-normal distribution with a peak and a width that is in excellent agreement with observations of multiple stellar systems if one adopts a core star formation efficiency of order 15%.

The final dynamical state of the newly formed stellar cluster closely resembles observed young stellar clusters. It has a core/halo structure which is typical for collision dominated N -body systems. The 2-point correlation function of the spatial stellar distribution can be described by two power-laws with a break in the slope at the transition point from the binary to the large-scale clustering regime. The protostellar cluster is marginally bound and would be easily

disrupted, if the conversion of cores into stars is inefficient.

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preprint at <http://www.strw.LeidenUniv.nl/~klessen/Preprints/p6.ps.gz> (87 pages including 27 figures, 11MB)

Thermally-Dominated Carbon Monoxide Emission in the Taurus Molecular Cloud Complex

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We analyze the structure of a region of the Taurus Molecular Cloud containing star-forming dense cores, as traced by emission from the $J = 1 \rightarrow 0$ rotational transition of the carbon monoxide isotopomer, $C^{18}O$. While the spatial structure of the velocity-integrated emission is rather featureless, there is substantial structure in the emission integrated over small velocity widths, and the entire three dimensional dataset (Right Ascension, Declination, velocity) can be broken into a collection of nearly discrete components. We construct a cloud model consisting of nine individual gaussian components and find that the data are best replicated when these components have sizes of ~ 0.1 pc and velocity dispersions comparable to or smaller than the thermal velocity dispersion of molecular hydrogen at a temperature of 10 K. We find that nearly all of the molecular mass of the cloud is contained within these quiescent structures. At least two of the structures are detected in observations in the $J = 4 \rightarrow 3$ line of HC_3N ; these two structures are likely associated with the two forming stars in the region. Our results suggest that thermally-dominated structures may be common in regions containing dense cores, but that many of these structures are insufficiently dense to be detected with dense gas tracers.

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ISO-SWS spectroscopy of gas-phase C_2H_2 and HCN toward massive young stellar objects

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Observations of gas-phase C_2H_2 and HCN along the line of sight toward a large sample of deeply embedded massive young stellar objects (YSOs) have been performed using the Short Wavelength Spectrometer on board the Infrared Space Observatory. The ν_5 vibration-rotation band of C_2H_2 around $13.7 \mu m$ and the ν_2 band of HCN around $14.0 \mu m$ have been detected for most lines of sight. These wavelength regions are heavily affected by instrumental fringing and a detailed discussion of the data reduction techniques is given. Comparison with model spectra allows the excitation temperatures and the abundances of the molecules to be determined. The inferred excitation temperatures range from < 100 to 1000 K, and correlate well with each other, indicating that the two molecules probe the same warm gas component. The C_2H_2 and HCN column densities increase by more than an order of magnitude with increasing excitation temperature, and with the amount of heating of the ices. The corresponding abundances of C_2H_2 and HCN in the warm gas increase from $\sim 10^{-8}$ to $\sim 10^{-6}$ with increasing temperatures. The enhanced abundances are compared with a variety of chemical models. The observed gas-phase C_2H_2 most likely results from direct evaporation of interstellar ices, where C_2H_2 must be present at an abundance of $\sim 0.1 - 0.5\%$ with respect to H_2O ice. This abundance is consistent with the measured amount of C_2H_2 in cometary ices. The observed gas-phase HCN abundance shows a stronger increase with temperature and results from a combination of evaporation of ices and high-temperature gas-phase chemistry in the hot core.

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UV spectra of T Tauri stars from Hubble Space Telescope: RY Tau (and HD 115043).

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UV spectra of RY Tau and HD 115043 observed with HST/GHRS were analyzed. RY Tau is a classical T Tauri star and HD 115043 is a young ($t \sim 3 \cdot 10^8$ yrs.) star with enhanced chromospheric activity. Almost all lines were identified and their fluxes were measured.

Practically the same emission lines are seen in low resolution spectra of both stars between 1160 and 1760 Å. At the same time RY Tau line luminosity ~ 300 times larger than that of HD 115043, and relative line intensities in their spectra differ significantly. CIV 1550, Si IV 1400 and NV 1240 doublet components flux ratio is close to 1:2 in spectra of both stars. One can conclude from continuum SED that spectral type of RY Tau is more late than that of HD 115043. Simultaneous variability of RY Tau CIV 1550 and He II 1640 line fluxes (flare-like event) with characteristic time ~ 20 minutes was found. The increasing of the lines flux have accompanied by redshift of the lines profile maximum up to 50 km/s.

RY Tau line profiles were investigated from medium resolution spectra. It appeared that optically thin Si III] 1892 and C III] 1909 lines as well as optically thick components of CIV 1550 doublet have asymmetric profiles with FWHM near 300 km/s. Observed profiles of Mg II 2800 doublet components are also asymmetric, but apparently it is the result of superposition of IS absorption feature onto symmetrical broad ($\simeq 750$ km/s at the base) stellar emission line, redshifted relative laboratory wavelength to $\simeq 20$ km/s. Mg II 2800 doublet components flux ratio $\simeq 1.4$. It is not clear if emission lines of molecular hydrogen are present in RY Tau spectra.

It follows from the analysis that RY Tau UV emission lines can not originate in hydrostatically equilibrium chromosphere. I argue that the reason of the line emission is quasy-stationary accretion of circumstellar matter.

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An infrared proper motion study of the Orion bullets

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We report the first IR proper motion measurements of the Herbig-Haro objects in the Orion Molecular Cloud–One using a four-year time baseline. The [Fe II] emitting bullets are moving of order 0.08 arcsec per year, or at about 170 km s^{-1} . The direction of motion is similar to that inferred from their morphology. The proper motions of H₂ emitting wakes behind the [Fe II] bullets, and of newly found H₂ bullets, are also measured. H₂ bullets have smaller proper motion than [Fe II] bullets, while H₂ wakes with leading [Fe II] bullets appear to move at similar speeds to their associated bullets. A few instances of variability in the emission can be attributed to dense, stationary clumps in the ambient cloud being overrun, setting up a reverse-oriented bullet. Differential motion between [Fe II] bullets and their trailing H₂ wakes is not observed, suggesting that these are not separating, and also that they have reached a steady-state configuration over at least 100 years. The most distant bullets have, on average, larger proper motions, but are not consistent with free expansion. Nevertheless an impulsive, or short-lived ($\ll 1,000$ years) duration for their origin seems likely.

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<http://www.phys.unsw.edu.au/~jklee/research.html>

Characterizing the structure of interstellar turbulence

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Modeling the structure of molecular clouds depends upon good methods to statistically compare simulations with observations in order to constrain the models. Here we characterize a suite of hydrodynamical and magnetohydrodynamical (MHD) simulations of supersonic turbulence using an averaged wavelet transform, the Δ -variance, that has been successfully used to characterize observations. We find that, independent of numerical resolution and dissipation, the only models that produce scale-free, power-law Δ -variance spectra are those with hypersonic rms Mach numbers, above $M \sim 4$, while slower supersonic turbulence tend to show characteristic scales and produce non-power-law spectra. Magnetic fields have only a minor influence on this tendency, though they tend to reduce the scale-free nature of the turbulence, and increase the transfer of energy from large to small scales. The evolution of the characteristic length scale seen in supersonic turbulence follows exactly the $t^{1/2}$ power-law predicted from recent studies of the kinetic energy decay rate.

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A search for precursors of Ultracompact HII Regions in a sample of luminous IRAS sources. III: Circumstellar Dust Properties

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The James Clerk Maxwell Telescope has been used to obtain submillimeter and millimeter continuum photometry of a sample of 30 IRAS sources previously studied in molecular lines and centimeter radio continuum. All the sources have IRAS colours typical of very young stellar objects (YSOs) and are associated with dense gas. In spite of their high luminosities ($L \gtrsim 10^4 L_\odot$), only ten of these sources are also associated with a radio counterpart. In 17 cases we could identify a clear peak of millimeter emission associated with the IRAS source, while in 9 sources the millimeter emission was either extended or faint and a clear peak could not be identified; upper limits were found in 4 cases only.

The submm/mm observations allow us to make a more accurate estimate of the source luminosities, typically of the order of $10^4 L_\odot$. Using simple greybody fitting model to the observed spectral energy distribution, we derive global properties of the circumstellar dust associated with the detected sources. We find that the dust temperature varies from 24 K to 45 K, while the exponent of the dust emissivity *vs* frequency power-law spans a range $1.56 < \beta < 2.38$, characteristic of silicate dust; total circumstellar masses range up to more than $500 M_\odot$.

We present a detailed analysis of the sources associated with millimeter peaks, but without radio emission. In particular, we find that for sources with comparable luminosities, the total column densities derived from the dust masses do not distinguish between sources with and without radio counterpart. We interpret this result as an indication that dust does not play a dominant role in inhibiting the formation of the HII region. We examine several scenarios for their origin in terms of newborn ZAMS stars and although most of these (e.g. optically thick HII regions, dust extinction of Lyman photons, clusters instead of single sources) fail to explain the observations, we cannot exclude that these sources are young stars already on the ZAMS with modest residual accretion that quenches the expansion of the HII region, thus explaining the lack of radio emission in these bright sources. Finally, we consider the possibility that the IRAS sources are high-mass pre-ZAMS (or pre-H-burning) objects deriving most of the emitted luminosity from accretion.

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New PAH mode at 16.4 μm

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The detection of a new 16.4 μm emission feature in the ISO-SWS spectra of NGC 7023, M17, and the Orion Bar is reported. Previous laboratory experiments measured a mode near this wavelength in spectra of PAHs (Polycyclic Aromatic Hydrocarbons), and so we suggest the new interstellar 16.4 μm feature could be assigned to low-frequency vibrations of PAHs. The best carrier candidates seem to be PAH molecules containing pentagonal rings.

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Growth of an IMF-Cluster in a Turbulent Dense Core

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A simple model of condensation growth and collapse in a turbulent dense core yields a distribution of stellar masses which matches the main features of the stellar initial mass function (IMF). In this model, stars in the “flat” and “power-law” parts of the IMF come from condensations with negligible and substantial growth, respectively. The mass accretion rate of a condensation is proportional to its mass, and the probability of stopping accretion is equal in every time interval, so the growth is exponential and its duration follows a Poisson distribution. For mass growth e-folding time τ_{grow} and mean duration τ_{stop} , the stellar mass m has probability density per logarithmic mass interval $\sim m^{-x}$, where $x \equiv \tau_{grow}/\tau_{stop}$. This power-law relation has $x \approx 1$ as for the IMF when $\tau_{grow} \approx \tau_{stop}$, as is expected if each of these times is set by the same properties of the surrounding core gas. We specify exponential growth due to Bondi accretion onto a stationary Bonnor-Ebert sphere, in a core heated and stirred by associated stars. This growth is exponential, unlike Bondi accretion onto a star, but “slow,” with τ_{grow} greater than the free-fall time of the condensation by a factor ~ 4 . We specify random stopping due to sudden turbulent compression, which causes the condensation to collapse and stop accreting. For these mechanisms, a core with density 10^4 cm^{-3} grows a cluster of ~ 100 IMF-following stars with mass range 1–25 M_{\odot} in 1.4 Myr, in accord with the masses and ages of embedded clusters.

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Evolution of Protostars Accreting Mass at Very High Rates: Is Orion IRC2 a Huge Protostar ?

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The recent near-infrared spectroscopy of scattered light from Orion IRC2 suggests that the illuminating source at K' -band is either a protostar with a radius $\geq 300R_{\odot}$ or a disk with an accretion rate $\approx 10^{-2}M_{\odot} \text{ yr}^{-1}$. To test the former interpretation we present a simplified stellar model accreting mass at very high rate $\approx 10^{-2}M_{\odot} \text{ yr}^{-1}$. We find that the protostar is fully convective at almost all stages of the stellar mass $M \leq 15M_{\odot}$, and thus a polytrope of index 1.5 is a good approximation to the stellar structure. The maximum radius $\leq 30R_{\odot}$ is attained at $M \sim 7M_{\odot}$. The shell deuterium burning, which would occur afterwards, cannot greatly blow up the protostar because the energy

released by deuterium burning is small and also because the protostar is already shrinking rapidly. The only remaining possibility to make a huge protostar resides in the rotation of the surface layer almost at its break-up velocity. On the other hand we find no difficulty in the alternative interpretation that the illuminating source is the accretion disk. In this case we predict that the $2.3\ \mu\text{m}$ CO absorption lines should be observed with a width $\sim 50\ \text{km s}^{-1}$ due to the Keplerian motion in the disk. The accretion rate as high as $10^{-2}M_{\odot}\text{ yr}^{-1}$ is compatible with the velocity dispersion in the Orion KL molecular cloud core. Because the luminosity of IRc2 is dominated by accretion, the protostellar mass is overestimated if the observed luminosity is regarded intrinsic. Because the K' -band luminosity is emitted in the disk region far from the protostellar surface, the total accretion luminosity must be significantly higher than the observed K' -band luminosity.

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Planetesimal Formation in the Solar Nebula

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We present a series of 2-dimensional hydrodynamical simulations of marginally self gravitating ($M_D/M_{\star} = 0.2$, with $M_{\star} = 0.5M_{\odot}$ and with disk radius $R_D = 50$ and 100 AU) disks around protostars using a Smoothed Particle Hydrodynamic (SPH) code. We implement simple and approximate prescriptions for heating via dynamical processes in the disk. Cooling is implemented with a simple radiative cooling prescription which does not assume that local heat dissipation exactly balances local heat generation. Instead, we compute the local vertical (z) temperature and density structure of the disk to obtain photospheric temperature, which is then used to cool that location as a black body. We synthesize spectral energy distributions (SEDs) for our simulations and compare them to fiducial SEDs derived from observed systems, in order to understand the contribution of dynamical evolution of the observable character of a system.

We find that these simulations produce less distinct spiral structure than isothermally evolved systems, especially in approximately the inner radial third of the disk. Pattern amplitudes are similar to isothermally evolved systems further from the star but do not collapse into condensed objects. We attribute the differences in morphology to increased efficiency for converting kinetic energy into thermal energy in our current simulations. Our simulations produce temperatures in the outer part of the disk (~ 10 K). The radial temperature distribution at the disk photosphere is well fit to a power law with index $q \approx 1.1$. Far from the star, corresponding to colder parts of the disk and long wavelength radiation, known internal heating processes (PdV work and shocks) are not responsible for generating a large fraction of the thermal energy contained in the disk matter. Therefore gravitational torques responsible for such shocks cannot transport mass and angular momentum efficiently in the outer disk.

Within $\sim 5 - 10$ AU of the star, rapid breakup and reformation of spiral structure causes shocks, which provide sufficient dissipation to power a larger fraction of the near infrared radiated energy output. In this region, the spatial and size distribution of grains can have marked consequences on the observed near infrared SED of a given disk, and can lead to increased emission and time variation on ≤ 10 year time scales. The inner disk heats to the destruction temperature of dust grains. Further temperature increases are prevented by efficient cooling when the hot disk midplane is exposed. When grains are vaporized in the midplane of a hot region of the disk, we show that they do not reform into a size distribution similar to that from which most opacity calculations are based. With rapid grain reformation into original size distribution, the disk does not emit near infrared photons. With a plausible modification of the opacity, it contributes much more.

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5 cm OH Masers as Diagnostics of Physical Conditions in Star-Forming Regions

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We demonstrate that the observed characteristics of the 5 cm OH masers in star-forming regions can be explained with the same model and the same parameters as the 18 cm and the 6 cm OH masers. In our already published study of the 18 cm and the 6 cm OH masers in star-forming regions we had examined the pumping of the 5 cm masers, but did not report the results we had found because of some missing collision rate coefficients, which in principle could be important. The recently published observations on the 5 cm masers of OH encourage us to report our old calculations along with some new ones that we have performed. These calculations, in agreement with the observations, reveal the main lines at 5 cm as strong masers, the 6049 MHz satellite line as a weak maser, and the 6017 MHz satellite line as never inverted for reasonable values of the parameters.

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The emergence of a neutral Herbig-Haro jet into a photoionized nebula

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Recent observations show the existence of an increasing number of collimated outflows ejected by young, low mass stars which are embedded in H II regions. At distances of a few tens of astronomical units from the star, at least one lobe of these outflows will be shielded from the ambient ionizing radiation by the compact, high extinction circumstellar disk. Within these shielded regions, the jets are probably mostly neutral, similar to the jets in “normal” Herbig-Haro (HH) objects. At larger distances, these jets emerge into the photoionized nebula, and start to be photoionized by the radiation from the ionizing photon source of the nebula.

In this paper, we model the photoionization of an initially neutral HH jet. This process begins as an ionization front at the side of the jet which is directed towards the ionizing star of the nebula, and progresses into the beam of the jet. There are two possible solutions. In the first solution, the jet beam becomes fully ionized through the passage of an R-type ionization front. In the second solution, the ionization front slows down enough to become a D-type front (or is already a D-type front at the point in which the jet emerges into the photoionized nebula), forming a partially ionized jet beam, with an expanding photoionized region and a compressed neutral region.

We explore these two types of solutions both analytically and numerically, and discuss the observational effects introduced by this jet photoionization process, concentrating in a region of parameter space that straddles the parameters deduced for HH 444 (the jet from V 510 Orionis).

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Cloud Collision-Induced Star Formation in Sagittarius B2. I. Large-Scale Kinematics

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We present maps of a ~ 14 pc \times 20 pc region covering the Sgr B2 molecular cloud complex in the ¹³CO (1 – 0) and CS

(1 – 0) lines with high angular resolution. A more restricted central area was also mapped in the $C^{18}O$ (1 – 0) line. The ^{13}CO cloud consists of two components: a compact core of ~ 3 pc in diameter roughly centered on Sgr B2 (M) and an extended plateau of ~ 17 pc \times 7.5 pc area containing the maser sources and most of the HII regions. Compact, massive ($\sim 3 \times 10^5 M_{\odot}$) $C^{18}O$ cores are associated with Sgr B2(M) and Sgr B2(N). The obtained intensity distributions are compared with those of molecular masers and compact HII regions reported in the literature. Low-velocity (40 – 65 km s $^{-1}$) masers, with positions roughly aligned in the north–south line connecting the three major compact HII region complexes, are located near the eastern margin of a large hole in the low-velocity molecular cloud. In contrast, most of the high-velocity (65 – 80 km s $^{-1}$) masers are distributed near the center of a compact molecular cloud at higher velocity, where a shock seems to have occurred. These results provide further evidence supporting the cloud–cloud collision hypothesis based on limited ^{13}CO (1 – 0) data (Hasegawa et al. 1994). In addition, this hypothesis appears to be consistent with a wide range of new observations that have appeared in the literature.

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Giant protostellar outflows revealed by infrared imaging

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We present new infrared data from a survey for embedded protostellar jets in the Orion A cloud. This survey makes use of the S(1) v = 1–0 line of molecular hydrogen at $\lambda = 2.12 \mu\text{m}$ to search for infrared jets deep inside the cloud and thus hidden from view at optical wavelengths. We present data on the three flows associated with the Herbig-Haro objects HH 43/38 & HH 64, HH 65, and the L1641-N giant flow. HH 43, HH 38 and HH 64 are part of one H₂ flow extending over at least 1.4 pc. We identify a deeply embedded 1.3 mm and IRAS source (HH 43 MMS1 = IRAS 05355–0709C) as the likely driving source, while the infrared source previously assumed to drive HH 43/38 (HH 43-IRS1 = IRAS 05357–0710) is seen to drive a smaller jet. The morphology of HH 43-IRS1 suggests that it is a star+disk system seen close to edge-on. We identify another large H₂ flow apparently comprising the L1641-S3 CO outflow and the redshifted lobe of the L1641-S CO outflow containing HH 65. This flow extends over at least 2.6 pc and appears strongly curved. It is driven by L1641-S3 IRS, a deeply embedded 1.3 mm and IRAS source (L1641-S3 MMS1 = IRAS 05375–0731). Finally, we have found some additional large H₂ features to the east of V 380 Ori and the HH 1/2 system, which probably outline another part of the L1641-N outflow. The molecular flow MB 20/21, which extends to the south from V 380 Ori, also appears to be a part of the L1641-N outflow.

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Preprint available at: <ftp://ftp.aip.de/pub/users/stanke/papers/irgiantflows.ps.gz>

Two-Millimeter Observations of Bright-Rimmed Clouds with IRAS Point Sources

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We have made 2 mm continuum observations of fifteen bright-rimmed clouds (BRCs) associated with IRAS point sources and S 140 with Nobeyama Bolometer Array (NOBA) mounted on the 45 m telescope of Nobeyama Radio Observatory. Continuum emission was detected in five BRCs and S 140. These five BRCs are known to be associated with near-infrared YSO clusters mostly on the side facing toward the exciting star(s) and, therefore, are likely the sites of small-scale sequential star formation. The detected emission peaks of these five sources correspond to the IRAS positions within the positional errors and the IRAS sources are considered to be protostars (Class 0/I-like sources) which were formed most recently in the BRCs. Four of them are clearly extended more than the telescope beam, suggesting the presence of circumstellar structures. The circumstellar masses derived from the 2 mm continuum are

$\sim 5\text{-}90 M_{\odot}$, which are more massive than those of the nearby Class 0/I objects ($< \sim 1 M_{\odot}$). This fact and the relatively large bolometric luminosities of these objects suggest that the mass of the cluster or star(s) most recently formed in these BRCs could be higher than those of the previously formed stars formed in the near-infrared cluster. The comparisons with previous observations of Bok globules unassociated with bright rims and other objects are discussed. Most noteworthy is the fact that the ratios of the bolometric luminosity to the circumstellar mass are significantly higher in these BRCs than in Bok globules.

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ISO Spectroscopy of Young Intermediate-Mass Stars in the BD+40°4124 Group

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We present the results of ISO SWS and LWS grating scans towards the three brightest members of the BD+40°4124 group in the infrared: BD+40°4124 (B2Ve), LkH α 224 (A7e) and the embedded source LkH α 225. Emission from the pure rotational lines of H₂, from ro-vibrational transitions of CO, from PAHs, from H I recombination lines and from the infrared fine structure lines of [Fe II], [Si II], [S I], [O I], [O III] and [C II] was detected. These emission lines arise in the combination of a low-density ($\approx 10^2 \text{ cm}^{-3}$) H II region with a clumpy PDR in the case of BD+40°4124. The lower transitions of the infrared H I lines observed in BD+40°4124 are optically thick; most likely they arise in either a dense wind or a circumstellar disk. This same region is also responsible for the optical H I lines and the radio continuum emission. In the lines of sight towards LkH α 224 and LkH α 225, the observed emission lines arise in a non-dissociative shock produced by a slow ($\approx 20 \text{ km s}^{-1}$) outflow arising from LkH α 225. Toward LkH α 225 we also observe a dissociative shock, presumably located closer to the outflow source than the non-dissociative shock. In the line of sight towards LkH α 225 we observed absorption features due to solid water ice and amorphous silicates, and due to gas-phase H₂O, CO and CO₂. No solid CO₂ was detected towards LkH α 225, making this the first line of sight where the bulk of the CO₂ is in the gas-phase.

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<http://cfa-www.harvard.edu/~mancker/publist.html>

Alfvénic Heating of Protostellar Accretion Disks

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We investigate the effects of heating generated by damping of Alfvén waves on protostellar accretion disks. Two mechanisms of damping are investigated, nonlinear and turbulent, which were previously studied in stellar winds (Jatenco-Pereira & Opher 1989a, b). For the nominal values studied, $f = \delta v/v_A = 0.002$ and $F = \varpi/\Omega_i = 0.1$, where δv , v_A and ϖ are the amplitude, velocity and average frequency of the Alfvén wave, respectively, and Ω_i is the ion cyclotron frequency, we find that viscous heating is more important than Alfvén heating for small radii. When the radius is greater than 0.5 AU, Alfvénic heating is more important than viscous heating. Thus, even for the relatively small value of $f = 0.002$, Alfvénic heating can be an important source of energy for ionizing protostellar disks, enabling angular momentum transport to occur by the Balbus-Hawley instability.

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Dense Cores of Dark Clouds.XII. ^{13}CO and C^{18}O in Lupus, Corona Australis, Vela, and Scorpius

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dense condensations of the dark clouds in Lupus, Corona Australis, Norma, Vela and Scorpius were observed in the ^{13}CO and C^{18}O ($J=1-0$) transitions. The condensations of dark clouds with high star formation activity like the Ophiuchus, Taurus, and Cepheus have average C^{18}O and H_2 column densities $1.8 \times 10^{15} \text{ cm}^{-2}$ and $1.1 \times 10^{22} \text{ cm}^{-2}$. Taking the average size of the condensations 0.2 pc, a condensation must have average H_2 volumetric densities $\geq 2 \times 10^4 \text{ cm}^{-3}$ in order to be a good candidate to form stars. The four Lupus filaments have similar radial velocity and velocity dispersion suggesting that they originated from the same parental cloud. Among these filaments, Lupus 1 is unique with recent star formation activity, despite the high number of T Tauri stars observed toward the other ones. Lupus 1 also shows a complex velocity gradient along its main axis. The distribution of radial velocities of the condensations observed toward Scorpius are in good agreement with the hypothesis that they are in a region with expansion velocity smaller or equal to 18 kms^{-1} . The Corona Australis cloud has velocity gradient changing between $-0.5 \text{ kms}^{-1} \text{ pc}^{-1}$ at one extreme to $0.1 \text{ kms}^{-1} \text{ pc}^{-1}$ at the other.

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Hydrocarbons in diffuse and translucent clouds

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We investigate the consequences on hydrocarbon chemistry in diffuse and translucent clouds of including an interaction between gaseous C^+ ions and dust grains. In general, we find that models in which much of the carbon is deposited and retained on grain surfaces within the cloud lifetime represent a poor match to observations. Conversely, models in which carbon is efficiently converted to methane generally provide satisfactory agreement with the observed chemistry of translucent clouds. Such models also predict that the hydrocarbons C_2H , C_3H_2 and H_2CO may be detectable in diffuse clouds.

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Modeling Non-Axisymmetric Bow Shocks: Solution Method and Exact Analytic Solutions

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A new solution method is presented for steady-state, momentum-conserving, non-axisymmetric bow shocks and colliding winds in the thin-shell limit. This is a generalization of previous formulations to include a density gradient in the pre-shock ambient medium, as well as anisotropy in the pre-shock wind. For cases where the wind is unaccelerated, the formalism yields exact, analytic solutions.

Solutions are presented for two bow shock cases: (1) that due to a star moving supersonically with respect to an ambient medium with a density gradient perpendicular to the stellar velocity, and (2) that due to a star with a misaligned, axisymmetric wind moving in a uniform medium. It is also shown under quite general circumstances that the total rate of energy thermalization in the bow shock is independent of the details of the wind asymmetry, including the orientation of the non-axisymmetric driving wind, provided the wind is non-accelerating and point-symmetric. A typical feature of the solutions is that the region near the standoff point is tilted, so that the star does not lie along the bisector of a parabolic fit to the standoff region. The principal use of this work is to infer the origin of bow shock asymmetries, whether due to the wind or ambient medium, or both.

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Dissertation Abstracts

Observational Constraints on the Formation and Evolution of Multiple Star Systems

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Ph.D degree awarded: November 1999

Presented is a high spatial resolution ultra-violet, optical and near-infrared imaging survey of 44 young binary stars in Taurus-Auriga with separations of 10 - 1000 AU. The observations were carried out using the WFPC2 aboard the Hubble Space Telescope and speckle and direct imaging at NASA's IRTF. These measurements are used to determine the stellar and circumstellar properties of binary star components in order to understand their formation and the effects of a close companion on circumstellar material.

The results of this study strongly favor fragmentation as the dominant binary star formation mechanism based on the coeval ages of binary stars, the distribution of mass ratios and secondary masses, the evidence for circumbinary material and the relative circumstellar properties; capture and disk instabilities are ruled out. In addition, several important conclusions are drawn regarding the evolution of circumstellar material in binary systems. The mass accretion rates for primary stars are similar to single stars, which suggests that a companion as close as 10 AU has little effect on the mass accretion rate. These accretion rates, if constant, require replenishment of the inner circumstellar disks. The higher frequency and larger accretion rates of circumprimary disks compared to circumsecondary disks favors replenishment from a low angular momentum, circumbinary reservoir in which material infalls toward the center of mass. The relative T Tauri types and binary mass ratios tentatively suggest that systems with separations less than ~ 200 AU share a common circumbinary reservoir.

A spectroscopic case study of the young quadruple GG Tau shows that the relative ages of binary stars offer a powerful test of evolutionary models and the temperature scale for young, low mass stars. The evolutionary models of Baraffe et al. (1998) are shown to yield the most consistent ages using a temperature scale intermediate between that of dwarf and giant stars. The lowest mass component of this system, GG Tau Bb, appears to be substellar with a mass of only $0.044 M_{\odot}$. GG Tau Bb is currently the lowest mass, spectroscopically confirmed companion to a T Tauri star, and is one of the coldest, lowest mass T Tauri objects in the Taurus-Auriga star forming region.

New Jobs

Postdoctoral Fellowships at the American Museum of Natural History, New York

The American Museum of Natural History is seeking proposals for innovative research in collaboration with museum faculty in the fields of the structure of star-forming clouds and the interstellar medium (M. Mac Low) and cataclysmic binaries, stellar populations and globular clusters (M. Shara).

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Applicants **MUST** contact the Department of Astrophysics to discuss their interests and background before applying in order to determine departmental interest.

Application on prescribed forms must be received by February 29, 2000.

For information please contact

Dr. Mordecai-Mark Mac Low Department of Astrophysics American Museum of Natural History New York, NY 10024-5192 email: mordecai@amnh.org

Application forms can also be downloaded from:

<http://research.amnh.org/grants/index.html>

Star Formation Postdoc at the University of Florida

The Department of Astronomy at the University of Florida, Gainesville invites applications for a postdoctoral position in observational studies of star formation. The successful applicant will work closely with a team of astronomers at UF, CFA and ESO. The Postdoc's primary responsibility will be to oversee a deep wide field near-IR spectroscopic and imaging survey of nearby molecular clouds using the newly commissioned FLAMINGOS wide field near-IR imager and multi-object spectrometer (<http://www.astro.ufl.edu/elston/flamingos/flamingos.html>). A key goal of this survey is to study the distribution of star formation within molecular clouds, the origin of the initial mass function and the evolution of circumstellar material. We expect roughly 30-40 nights per year of observing time will be dedicated to this program.

Applicants should have a recent Ph.D. and should preferably have experience with and interest in star formation, reduction of near-IR imaging and multi-object spectroscopic data. The position will begin in August or September 2000 and is funded for up to three years. For further information contact Elizabeth Lada at the Astronomy Department, 211 Bryant Space Science Building, University of Florida, Gainesville, FL 32608. Applicants should submit a curriculum vita, bibliography and a statement of research interests, and should arrange for three letters of reference to be sent to the above address. Review of applications will begin on March 1, 2000 and continue until the position is filled. The University of Florida is an equal opportunity employer.

Elizabeth Lada

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Postdoctoral Fellowship
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The star formation group at the Thüringer Landessternwarte Tautenburg invites applications for a postdoctoral fellowship in the field of star formation.

The successful applicant will work with Dr. J. Eislöffel on HST data of outflows from young stars. Our group currently comprises three faculty and six post-grads, working on low- and high-mass star formation, and on substellar objects. We are operating a 2-m ZEISS Universal telescope, and have access to German national and ESO facilities.

Candidates with a Ph.D. in astronomy or in a closely related field who can contribute to this research are invited to apply. The appointment will be for three years, and may start as early as April 1, pending confirmation of funding. The salary will be on the German BAT-O IIa scale and depends on age and marital status. Informal enquiries can be made to jochen@tls-tautenburg.de or to guenther@tls-tautenburg.de. Review of applications will begin 1 March 2000 and continue until the position is filled. Applicants should send a curriculum vitae, bibliography and statement of research interests and arrange for three letters of recommendation to reach Dr. J. Eislöffel at the above address.

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 Books

The Physics and Chemistry of the Interstellar Medium

Edited by Volker Ossenkopf, Jürgen Stutzki, and Gisbert Winnewisser

These are the proceedings of the 3rd Cologne-Zermatt Symposium, held at Zermatt, Switzerland on September 22-25, 1998. The meeting attracted 193 participants from around the globe, and spanned a wide range of topics related to the interstellar medium. Particular discussions were focused on the recent results from the Infrared Space Observatory, on systematic progress in interferometric observations, and on new detailed theoretical models developed to understand the interstellar medium in a more self-consistent physical interpretation. Below is listed the six sections and additionally the review chapters of the book.

Sect. 1 Interstellar Matter in External Galaxies

Sect. 2 The ISM in the Milky Way

Phases and Structures of Interstellar Gas *B. Elmegreen*

Large-Scale Molecular Surveys of the Galaxy and M31 *T.M. Dame*

Sect. 3 Molecular Clouds

Infrared Extinction and the Structure of Dark Clouds *C.J. Lada, J. Alves, & E.A. Lada*

The Structure of the Interstellar Medium: Observational Constraints *J. Stutzki*

Sect. 4 Star-Forming Regions

Initial Conditions and Motions in Star-Forming Dense Cores *P.C. Myers*

Sect. 5 Astrochemistry and Laboratory Astrophysics

Recent Developments in Astrochemistry *E.F. van Dishoeck*

Carbon Chains and Exotic Rings in the Laboratory and in Space *P. Thaddeus & M.C. McCarthy*

Sect. 6 Observatories, Telescopes, and Instrumentation

Directions for Submillimeter and Far-Infrared Instrumentation *A.I. Harris*

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Optical and Infrared Spectroscopy of Circumstellar Matter

Edited by Eike W. Guenther, Bringfried Stecklum, and Sylvio Klose

In celebration of the 65th birthday of Josef Solf, a workshop was held at the Thüringer Landessternwarte Tautenburg, Germany, on 10-12 March 1999. The topic of the meeting was the role of spectroscopy in the study of outflows from young and old stars and their associated circumstellar matter. In the following is listed the seven sections of the book, together with a selection of the lengthier articles.

Sect. 1 Introductory Session

Spectroscopic Insight and the Physics of Circumstellar Matter: Josef Solf's Contribution to Astrophysics *K.-H. Böhm & S. Matt*

Sect. 2 Outflows of Young Stars

Circumstellar Disks, Microjets, and Herbig-Haro Objects in the Orion Nebula *C.R. O'Dell & J. Bally*

Photoevaporated Flow of the Cometary Knots in NGC 7293 *L. López-Martin et al.*

Near-IR Studies of Protostellar Outflows: Entrainment and Excitation of Molecular Gas *C.J. Davis, M.D. Smith & J. Eisloffel*

Integral Field 3D Spectroscopy in Outflows *J.A. Tedds, P.W.J.L. Brand & M.G. Burton*

The Spectroscopic Properties of Embedded Stellar Outflows *A. Noriega-Crespo*

An Approach to the Mass Determination of Outflows from Low-Mass Young Stellar Objects - The Special Case of L1551-IRS5 *C.V.M. Fridlund & R. Liseau*

The Evolution of Protostars & their Environments *M.D. Smith*

Imprints of Magnetic Fields in Formation and Propagation of Young Stellar Jets *M. Camenzind*

Sect. 3 Activity of Young Stars

X-ray Emission of Pre-Main Sequence Stars and their Spatial Distribution *R. Neuhäuser*

Sect. 4 Turbulence and Star Formation

MHD Turbulence in Star-Forming Clouds *M.-M. Mac Low, R. Klessen, & F. Heitsch*

Chemical Signatures of Interstellar Turbulence - The Formation of CH⁺ *R. Gredel*

Sect. 5 Interstellar Matter

Progress in Infrared Spectroscopy of Solid Matter *Th. Henning*

Cosmic Dust Formation and Dust Forming Systems *E. Sedlmayr*

Sect. 6 Outflows of Old Stars

M2-9, the Bête-Noire of Bipolar Planetary Nebulae *B. Balick*

Jets and Disks in Young Planetary Nebulae *L.F. Miranda*

Formation and Evolution of Planetary Nebulae *D. Schönberner & M. Steffen*

Sect. 7 Instrumentation

Integral Field 3D Spectroscopy: Techniques and Prospects *N. Thatte et al.*

LUCIFER - LBT NIR spectroscopic Utility with Camera and Integral-Field Unit for Extragalactic Research *H. Mandel et al.*

The FEROS Spectrograph *O. Stahl, A. Kaufer, & S. Tubbesing*

Star Formation and Extrasolar Planet Studies with Near-Infrared Interferometry on the LBT *T.M. Herbst & H.-W. Rix*

Sect. 8 Closing Session

Concluding Remarks *J. Solf*

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