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Abstracts of recently accepted papers

Evolution of Molecular Abundances in Protoplanetary Disks with Accretion Flow

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We investigate the evolution of molecular abundances in a protoplanetary disk in which matter is accreting toward the central star by solving numerically the reaction equations of molecules as an initial-value problem. We obtain the abundances of molecules, both in the gas phase and in ice mantles of grains, as functions of time and position in the disk.

In the region of surface density less than 10^2 g cm^{-2} (distance from the star $\gtrsim 10 \text{ AU}$ for the mass accretion rate $10^{-8} M_{\odot} \text{ yr}^{-1}$), cosmic rays are barely attenuated even on the midplane of the disk, and produce chemically active ions such as H_3^+ and He^+ . We find that through reactions with these ions considerable amounts of CO and N_2 , which are initially the dominant species in the disk, are transformed into CO_2 , CH_4 , NH_3 , and HCN. In the regions where the temperature is low enough for these products to freeze onto grains, they accumulate in ice mantles. As the matter migrates toward inner warmer regions of the disk, some of the molecules in the ice mantles evaporate. It is found that most of the molecules desorbed in this way are transformed into less volatile molecules by the gas-phase reactions, which then freeze out. Molecular abundances both in the gas phase and in ice mantles crucially depend on the temperature and thus vary significantly with the distance from the central star. Although molecular evolution proceeds in protoplanetary disks, our model also shows that significant amount of interstellar ice, especially water ice, survives and is included in ice mantles in the outer region of the disks.

We also find that the time scale of molecular evolution is dependent on the ionization rate and the grain size in the disk. If the ionization rate and the grain size are the same as those in molecular clouds, the time scale of the molecular evolution, in which CO and N_2 are transformed into other molecules, is about 10^6 yr , which is slightly smaller than the lifetime of the disk. The time scale for molecular evolution is larger (smaller) in the case of lower (higher) ionization rate or larger (smaller) grain size.

We compare our results with the molecular composition of comets, which are considered to be the most primitive bodies in our solar system. The molecular abundances derived from our model naturally explain the coexistence of oxidized ice and reduced ice in the observed comets. Our model also suggests that comets formed in different regions of the disk have different molecular compositions. Finally we give some predictions for future millimeter-wave and sub-millimeter-wave observations of protoplanetary disks.

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VLA Continuum Observations of Suspected Massive Hot Cores

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We present VLA continuum observations of 12 luminous IRAS sources with no previously detected or relatively weak centimeter continuum emission. Given these characteristics, the observed sources could be massive hot cores, containing OB stars in the early stages of formation. All the sources were observed at 3.6 cm and five were also observed at 7 mm. With one exception (IRAS 20216+4107), all sources were detected at 3.6 cm. Five of these detections are reported here for the first time. The centimeter continuum emission is consistent with that expected from photoionization by the more massive members of stellar clusters with the observed luminosities. However, other explanations (e. g. thermal jets) are possible for the relatively weak continuum emission observed. No 7 mm emission was detected in the five sources observed.

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<http://www.astrosmo.unam.mx/~luisfr/>

Unveiling the disk-jet system in the massive (proto)star IRAS 20126+4104

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We present the results of line and continuum observations towards the source IRAS 20126+4104, performed at 1.3 mm and 3.5 mm with the Plateau de Bure interferometer, from 350 μm to 2 mm with the James Clerk Maxwell telescope, and at 10 and 20 μm with the United Kingdom infrared telescope. The results fully confirm the findings of Cesaroni et al. (1997), namely that IRAS 20126+4104 is a very young stellar object embedded in a dense, hot core and lying at the centre of a rotating disk. The bipolar jet imaged by Cesaroni et al. (1997) in the 2.122 μm H₂ line is seen also in the SiO(2-1) transition, which allows to study the velocity field in the jet. A simple model is developed to obtain the inclination angle of the jet (and hence of the disk axis), which turns out to be almost perpendicular to the line of sight. By studying the diameter of the disk in different transitions and the corresponding line widths and peak velocities, one can demonstrate that the disk is Keplerian and collapsing, and thus compute the mass of the central object and the accretion luminosity. We show that if all the mass inducing the Keplerian rotation is concentrated in a single star, then this cannot be a ZAMS star, but more likely a massive *protostar* which derives its luminosity from accretion.

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<http://www.arcetri.astro.it/~starform/publ1999.htm>

H₂ emission from shocks in molecular outflows: the significance of departures from a stationary state

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We have computed the time-dependence of the H₂ rovibrational emission spectrum from molecular outflows. This emission arises in shock waves generated by the impact of jets, associated with low-mass star formation, on molecular gas. The shocks are unlikely to have attained a state of equilibrium, and so their structure will exhibit both C- and J-type characteristics. The rotational excitation diagram is found to provide a measure of the age of the shock; in the case of the outflow observed in Cepheus A West by the ISO satellite, the shock age is found to be approximately

1500 yr. Emission by other species, such as NH_3 and SiO , is also considered, as are the intensities of the fine structure transitions of atoms and ions.

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ISO observations toward the reflection nebula NGC 7023: A nonequilibrium ortho- to para- H_2 ratio

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We have observed the S(0), S(1), S(2), S(3), S(4) and S(5) rotational lines of molecular hydrogen (H_2) towards the peak of the photodissociation region (PDR) associated with the reflection nebula NGC 7023. The observed H_2 line ratios show that they arise in warm gas with kinetic temperatures $\sim 300 - 700$ K. However, the data cannot be fitted by an ortho- to para- (OTP) ratio of 3. An OTP ratio in the range $\sim 1.5 - 2$ is necessary to explain our observations. This is the first detection of a non-equilibrium OTP ratio measured from the H_2 pure-rotational lines in a PDR. The existence of a dynamical PDR is discussed as the most likely explanation for this low OTP ratio.

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Preprint available at <http://www.oan.es/preprints/>

Scale-Free Equilibria of Isopedic Polytropic Clouds

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We investigate the equilibrium properties of self-gravitating magnetized clouds with polytropic equations of state with negative index n . In particular, we consider scale-free isopedic configurations that have constant dimensionless spherical mass-to-flux ratio λ_r and that may constitute “pivotal” states for subsequent dynamical collapse to form groups or clusters of stars. For given $\Gamma = 1 + 1/n$, equilibria with smaller values of λ_r are more flattened, ranging from spherical configurations with $\lambda_r = \infty$ to completely flattened states for $\lambda_r = 1$. For a given amount of support provided by the magnetic field as measured by the dimensionless parameter H_0 , equilibria with smaller values of Γ are more flattened. However, logatropic (defined by $\Gamma = 0$) disks do not exist. The only possible scale-free isopedic equilibria with logatropic equation of state are spherical uniformly magnetized clouds.

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ISO-LWS Observations of Herbig Ae/Be Stars II: Molecular Lines

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We present the first ISO-LWS observations of the molecular FIR lines in 3 out of a sample of 11 Herbig Ae/Be stars (HAEBE), namely IRAS12496-7650, RCrA and LkH α 234. High- J rotational CO lines (from $J_{up} = 14$ to $J_{up} = 19$) have been observed in all the spectra, while two (at 79 μm and 84 μm) and three OH lines (at 71 μm , 79 μm and 84 μm) were detected in LkH α 234 and RCrA respectively.

For all sources the molecular emission has been consistently fitted with a Large Velocity Gradient (LVG) model and it results originated in a warm ($T \geq 200$ K) and dense ($n_{H_2} \geq 10^5$ cm $^{-3}$) gas located in very compact regions having diameters of few hundreds of AU.

These three sources are those with the highest density among the stars of the sample; this suggests that the molecular emission arises in regions showing density peaks.

By comparing the observed cooling ratios with model predictions, we find that the FUV radiation from the central source (or from a more embedded companion) is the most likely responsible for the line excitation. At least for the sources where OH has been observed, the contribution of shocks to the line emission can be reasonably ruled out because of the absence in the spectra of any water vapour lines, in contrast with the predictions for molecular emission coming from warm shocked environments.

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Preprints available through anonymous ftp: coma.mporzio.astro.it/pub/teresa/paperII.ps

Limits on HDS/H $_2$ S abundance ratios in hot molecular cores

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We have searched for HDS emission in a small number of hot cores. Using observations of H $_2^{34}$ S, we have derived upper limits to the [HDS]/[H $_2$ S] abundance ratio. The upper limits, which are close to 10^{-3} can be interpreted in two ways, depending on whether grain surface reactions contribute to the formation of H $_2$ S. If grains do not dominate, then the H $_2$ S observed is formed in hot, post-shocked gas and a ratio close to the cosmic [D]/[H] ratio is expected for [HDS]/[H $_2$ S]. This scenario is consistent with our upper limits and with the relatively low abundance ratio found for [HDO]/[H $_2$ O] in hot cores but does not seem to account for all of the molecular [D]/[H] ratios observed in hot cores. If grains do dominate the formation of H $_2$ S, then the observed upper limit to the ratio is consistent with the formation of ‘hot core ices’ at a temperature of 60–80 K, close to the temperature at which cometary ices are thought to form.

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<http://saturn.phy.umist.ac.uk:8000/~jjh/HDS.ps.gz>

Hot molecular bullets in HH 111 and Cep E

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Many protostellar outflows show high velocity molecular bullets, in addition to a low velocity molecular outflow and shocked H $_2$ knots. The velocities of these bullets suggests that they are closely related to the protostellar wind. We demonstrate from ^{12}CO 4–3 and lower- J ^{12}CO and ^{13}CO observations that the CO bullets are hot, as expected for

actively shocked molecular material. This upwardly revised temperature estimate implies that the bullets are more massive than was previously considered. The high masses have consequences for models of the origin of the bullets. They cannot consist of locally swept up material; they can form of material swept up along their path only if that path is much longer than the distance between the bullets; alternatively, if they consist of jet material then the jet must have a density of $\sim 10^4 \text{ cm}^{-3}$.

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<http://saturn.phy.umist.ac.uk:8000/~jjh/bullets.ps.gz>

A double system of ionized jets in IRAS 20126+4104

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We have imaged the 7 mm and 3.6 cm continuum emission from the high mass (proto)star system IRAS 20126+4104 with the VLA. The 7 mm emission appears unresolved with a synthesized beam of $1.7'' \times 1.0''$, and comparison with 3 mm and 1.3 mm fluxes indicates a spectral index of about 3, so that emission from dust with an absorption coefficient proportional to ν is suggested.

The 3.6 cm emission consists of two elongated structures of approximate size $0.8'' \times \leq 0.2''$, the northern source being coincident with the millimeter emission. The position angle of both sources is identical to the large scale molecular outflow seen in $\text{HCO}^+(1-0)$.

We discuss explanations for the origin of the 3.6 cm continuum emission and although a cluster of three ultracompact HII regions provides a feasible model, we favor the interpretation of thermal ionized jets, based on the morphology of the emission, the velocity distribution of water masers coincident with the northern source, and the CH_3CN emission which is oriented perpendicular to the 3.6 cm continuum emission. In this case the measured fluxes are consistent with ionization caused by either shocks or stellar UV photons.

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K band variability as a method to select YSO candidates

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A study of the applicability of *K* ($2.2 \mu\text{m}$) band variability as a method to separate young stellar objects (YSOs) from field stars in young embedded clusters is presented. Deep *K* band imaging of the central $\sim 8' \times 6'$ region of the Serpens Cloud Core was made at several epochs in 1995 and 1996. Variability in *K* was detectable at peak-to-peak amplitudes as small as typically $\Delta K = 0.15$ at a conservative 3σ level for sources brighter than $K \approx 15$. This level increases gradually to $\Delta K = 1.3$ at $K \approx 18$.

From a multi epoch sample of about 1000 stars ($K < 18$) a total of 55 stars have been found to exhibit variability in the *K* band at observed amplitudes from 0.15 to 2.2 magnitudes, and 9 of these have varied at several of the investigated epochs. 39 of the 55 variable sources were not previously recognized and are hereby proposed as new YSO candidates. Not less than 26% of the total sample of already known YSOs within this region were found to vary over the time-scale of only one year. We conclude that the *K*-variability method is efficient in finding low-luminosity young sources in deeply embedded clusters.

In addition, deep *J* ($1.25 \mu\text{m}$) and *H* ($1.65 \mu\text{m}$) imaging of the same region revealed 37 near-IR excess sources from their position in the *J*–*H*/*H*–*K* diagramme, and 17 of these are new. One additional YSO candidate was found from

association with nebulosity. The total of 57 new YSO candidates increase the currently recognized YSO population by 85% within the observed field. The K luminosity function continues to rise down to $K \approx 16$, and no turnover is found at $K > 16$ which might not be due to sample incompleteness. The new sources are probably very low mass pre-main-sequence stars and young brown dwarfs.

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Accretion in the Early Kuiper Belt II. Fragmentation

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We describe new planetesimal accretion calculations in the Kuiper Belt that include fragmentation and velocity evolution. All models produce two power law cumulative size distributions, $N_C \propto r^{-2.5}$ for radii $\lesssim 0.3$ –3 km and $N_C \propto r^{-3}$ for radii $\gtrsim 1$ –3 km. The power law indices are nearly independent of the initial mass in the annulus M_0 ; the initial eccentricity of the planetesimal swarm e_0 ; and the initial size distribution of the planetesimal swarm. The transition between the two power laws moves to larger radii as e_0 increases. The maximum size of objects depends on the intrinsic tensile strength S_0 ; Pluto formation requires $S_0 \gtrsim 300$ erg g⁻¹. The timescale to produce Pluto-sized objects τ_P is roughly proportional to M_0^{-1} and e_0 , and is less sensitive to other input parameters. Our models yield $\tau_P \approx 30$ –40 Myr for planetesimals with $e_0 = 10^{-3}$ in a minimum mass solar nebula. The production of several ‘Plutos’ and $\sim 10^5$ 50 km radius Kuiper Belt objects leaves most of the initial mass in 0.1–10 km radius objects that can be collisionally depleted over the age of the solar system. These results resolve the puzzle of large Kuiper Belt objects in a small mass Kuiper Belt.

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Preprints: <http://cfa-www.harvard.edu/kenyon/preprints.html>

Infrared Excess and Molecular Gas in the Galactic Worm GW46.4+5.5

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We have carried out high-resolution ($\sim 3'$) HI and CO line observations along one-dimensional cuts through the Galactic worm GW46.4+5.5. By comparing the HI data with *IRAS* data, we have derived the distributions of I_{100} excess and τ_{100} excess, which are respectively the 100 μm intensity and 100 μm optical depth in excess of what would be expected from HI emission. In two observed regions, we were able to make a detailed comparison of the infrared excess and the CO emission. We have found that τ_{100} excess has a very good correlation with the integrated intensity of CO emission, W_{CO} , but I_{100} excess does not. There are two reasons for the poor correlation between I_{100} excess and W_{CO} : firstly, there are regions with enhanced infrared emissivity without CO, and secondly, dust grains associated with molecular gas have a low infrared emissivity. In one region, these two factors completely hide the presence of molecular gas in the infrared. In the second region, we could identify the area with molecular gas, but I_{100} excess significantly underestimates the column density of molecular hydrogen because of the second factor mentioned above. We therefore conclude that τ_{100} excess, rather than I_{100} excess, is an accurate indicator of molecular content along the line of sight. We derive $\tau_{100}/N(\text{H}) = (1.00 \pm 0.02) \times 10^{-5} (10^{20} \text{ cm}^{-2})^{-1}$, and $X \equiv N(\text{H}_2)/W_{\text{CO}} \simeq 0.7 \times 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})^{-1}$. Our results suggest that I_{100} excess could still be used to estimate the molecular content if the result is multiplied by a correction factor $\xi_c \equiv < I_{100}/N(\text{H}) >_{\text{HI}} / < I_{100}/N(\text{H}) >_{\text{H}_2}$ ($\simeq 2$ in the second region), which accounts for the different infrared emissivities of atomic and molecular gas. We also discuss some limitations of this work, which could stem from using single-temperature model and the *IRAS* 60 μm intensity in estimating the dust optical depth along the line of sight.

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ISO-LWS Observations of Herbig Ae/Be Stars I: Fine Structure Lines

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We present the results of the first spectrophotometric survey of a sample of eleven Herbig Ae/Be stars (HAEBE) obtained with the Long Wavelength Spectrometer (LWS) on board the Infrared Space Observatory (ISO). The [OI] 63 μ m and the [CII] 158 μ m lines are observed in all the investigated sources, while the [OI] 145 μ m transition, due to its relative faintness, sometimes remains undetected. By comparing line intensity ratios with model predictions, photodissociation, due to the UV photons from the central star, results the dominating excitation mechanism although contributions of C-shocks to the [OI] emission cannot be ruled out. A clear example for the presence of a photodissociation region (PDR) illuminated by an HAEBE is shown by LWS spectroscopic mapping of NGC 7129. Some diagnostic probes of the radiation field and density are provided for the objects in our sample: these substantially agree with the known characteristics of both the star and its circumstellar environment, although the observed ratio [OI]63/[OI]145 tends to be smaller than predicted by PDR models. The most likely explanation for this behaviour is self-absorption at 63 μ m by cold atomic oxygen. Fine structure lines of the ionised species [OIII], [NII] were detected whenever the star had a spectral type of B0 or earlier; in particular, around the star CoD-42°11721, besides a compact HII region, evidence is given for an extended low electron density ionised region. Finally, molecular line emission is associated with stars powering a CO outflow, and clumpy PDR models, better than C-shock models, predict for them relative cooling (CO *vs* OI and CO *vs* OH) similar to the observed ones.

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Cross-calibrated VLA Observations of Water Maser and 1.3 cm Continuum Emission in IRAS 18162–2048 (= HH 80-81 IRS)

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We report simultaneous continuum (1.3 cm) and H₂O maser line observations, made with the Very Large Array (A configuration), toward IRAS 18162–2048, the luminous exciting source of the HH 80-81 complex. The continuum observations, cross-calibrated with the H₂O maser emission, provide information of the thermal jet of this young massive star with unprecedented angular resolution and fidelity. We find that the jet is already collimated on scales

smaller than 100 AU. The analysis of the new 1.3 cm data and of previously obtained 3.6 cm data show that the source has the frequency dependences in major axis and flux density that characterize biconical jets. In particular, we find $\theta_{\text{maj}} \propto \nu^{-0.7 \pm 0.1}$ and $S_\nu \propto \nu^{0.8 \pm 0.1}$. An improved determination of the mass loss rate in ionized gas, $\dot{M}_{\text{ion}} \simeq 9 \times 10^{-7} M_\odot \text{ yr}^{-1}$, is provided with these new observations.

As it was known from previous studies, the H₂O maser emission does not coincide with the thermal jet but with a faint source of radio continuum emission displaced by $\sim 7''$ to the northeast of the thermal jet. The H₂O masers appear in two compact clusters separated by ~ 20 mas. One of the clusters is formed by spots in a linear geometry. The kinematics of these maser spots and their large blueshift with respect to the radial velocity of the parental molecular cloud suggest that they trace material accelerated by outflow phenomena, instead of a possible disk.

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<http://www.astrosmo.unam.mx/~luisfr/>

Star Formation in the Vela Molecular Clouds III. Near IR Images and mm photometry of D-cloud IRAS sources

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We present the first results of a sensitive ($K \approx 17$ mag) near IR (JHK) imaging survey of a complete IRAS selected sample of Young Stellar Objects (YSO's) belonging to a Giant Molecular Cloud (GMC) located in the Vela Molecular Ridge (VMR). We provide accurate position and photometry for more than 1300 sources, along with the identification of possible NIR counterparts of the IRAS objects. Through near infrared and 1.3 mm photometry we have determined the spectral energy distributions of 11 newly discovered Class I sources and possibly one Herbig Ae/Be star. Their bolometric luminosities indicate that they are protostellar objects of intermediate masses ($\leq 10 M_\odot$) with envelopes containing a not negligible fraction of the central condensed matter. Many sources are associated to diffuse emission which hosts multiple systems of point-like objects. Although clustering is well evident, the NIR counterparts of the IRAS sources seem to be single objects and quite often there are more than one source in the field with JHK colours typical of Class I objects. These findings support the fact that in VMR, as well, stars of different masses are sharing the same birthplace.

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CCS Imaging of the Starless Core L1544: An Envelope with Infall and Rotation

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We have carried out observations of the starless core L1544 in the CCS ($J_N = 3_2 - 2_1$) line at 9 millimeters wavelength using the BIMA array. The maps show an elongated condensation, 0.15×0.045 pc in size, with stronger emission at the edges. The appearance is consistent with a flattened, ringlike structure viewed at high inclination to the line of sight. The CCS molecule is likely heavily depleted in the inner part of the core. The position velocity diagram along the major axis shows a remarkable pattern, a “tilted ellipse”, that can be reproduced by a simple model ring with

motions of both infall and rotation. The models suggest comparable velocities for infall and rotation, $\sim 0.1 \text{ km s}^{-1}$, in the outermost envelope, at radius 15000 AU.

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An extremely X-ray luminous proto–Herbig Ae/Be star in the Serpens star forming region

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We present near-infrared spectra for the highly obscured, optically invisible young stellar object EC 95 in the Serpens molecular cloud, from which we recently could detect strong X-ray emission with ROSAT. Its location in the HR diagram suggests this object to be an extremely young ($\sim 2 \times 10^5$ yr old) intermediate-mass ($\sim 4 M_{\odot}$) star, which is most likely the progenitor of a B-type or early A-type main sequence star. The only reasonable explanation for its extremely strong X-ray emission ($L_X \sim 1.2 \times 10^{33}$ erg/sec) seems to be coronal, i.e. magnetic activity; this view is also supported by the strong radio emission of EC 95. This is quite surprising, since one usually does not expect a magnetic field on intermediate-mass stars, which are thought to lack surface convection zones, the prerequisite for a solar-like dynamo effect. A possible explanation might be that EC 95 currently goes through a short period of deuterium shell burning, which causes convection near the stellar surface and might give rise to a dynamo effect and a corona.

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<http://www.astro.uni-wuerzburg.de/~preib/ec95.html>

The History of Low-Mass Star Formation in the Upper Scorpius OB Association

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We use a large sample of about 100 low-mass pre-main sequence (PMS) stars in the Upper Scorpius OB association to explore the star formation history and the IMF of this association. Upper Scorpius is an ideal target for such a study, because the star formation process there is finished. The PMS stars have recently been found in a spatially unbiased wide field survey of X-ray selected stars in a 160 square-degree area, covering the Upper Scorpius association nearly completely. Following the optical characterization of these PMS stars, we present a new HR diagram for this association. We perform a detailed analysis of the HR diagram, taking proper account of the uncertainties and the effects of unresolved binaries, and derive ages and masses for the PMS stars. We find that the low-mass PMS stars have a mean age of about 5 Myr and show no evidence for a large age dispersion. This agrees very well with the age of 5 – 6 Myr previously found for the massive stars and shows that low-mass and high-mass stars are coeval and co-spatial and thus have formed together. We conclude that the star formation process in Upper Scorpius was probably triggered by the shock wave of a supernova explosion in the nearby Upper Centaurus-Lupus association. After a short burst of very high star formation activity, which lasted only for a few Myr, star formation in Upper Scorpius was halted, probably by the strong winds and the ionizing radiation of the numerous massive stars which dispersed the molecular cloud.

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<http://www.astro.uni-wuerzburg.de/~preib/sco2.html>

The Balbus-Hawley instability in weakly ionised discs

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MHD in protostellar discs is modified by the Hall current when the ambipolar diffusion approximation breaks down. Here I examine the Balbus-Hawley (magnetorotational) instability of a weak, vertical magnetic field within a weakly-ionized disc. Vertical stratification is neglected, and a linear analysis is undertaken for the case that the wave vector of the perturbation is parallel to the magnetic field.

The growth rate depends on whether the initial magnetic field is parallel or antiparallel to the angular momentum of the disc. The parallel case is less (more) unstable than the antiparallel case if the Hall current is dominated by negative (positive) species. The less-unstable orientation is stable for χ less than about 0.5, where χ is the ratio of a generalised neutral-ion collision frequency to the Keplerian frequency. The other orientation has a formal growth rate of order the Keplerian angular frequency even in the limit that $\chi \rightarrow 0$! In this limit the wavelength of the fastest growing mode tends to infinity, so the minimum level of ionization for instability is determined by the requirement that a wavelength fit within a disc scale height. In the ambipolar diffusion case, this requires $\chi > v_A/c_s$; in the Hall case this imposes a potentially much weaker limit, $\chi > v_A^2/c_s^2$.

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A Contracting, Turbulent, Starless Core in the Serpens Cluster

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We present combined single-dish and interferometric CS(2–1) and N₂H⁺(1–0) observations of a compact core in the NW region of the Serpens molecular cloud. The core is starless according to observations from optical to millimeter wavelengths and its lines have turbulent widths and “infall asymmetry”. Line profile modeling indicates supersonic inward motions $v_{\text{in}} \geq 0.34 \text{ km s}^{-1}$ over an extended region $L > 12000 \text{ AU}$. The high infall speed and large extent exceeds the predictions of most thermal ambipolar diffusion models and points to a more dynamical process for core formation. A short (dynamic) timescale, $\sim 10^5 \text{ yr} \simeq L/v_{\text{in}}$, is also suggested by the low N₂H⁺ abundance $\sim 1 \times 10^{-10}$.

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