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Abstracts of recently accepted papers

New weak-line T Tauri stars in Orion from the ROSAT all-sky survey

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We present results of the spectroscopic and photometric follow-up observations of the *ROSAT* all-sky survey in the direction of the Orion cloud complex. The main goal of these observations is the search for X-ray emitting pre-main sequence stars. 820 X-ray sources were detected with high confidence in about 450 square degrees. The mean density of X-ray sources in this region is a factor of about two higher than that of the whole RASS. 5% of the RASS sources in this region are identified with previously known and likely pre-main sequence stars. We have investigated spectroscopically 181 new RASS sources widely distributed over the entire cloud complex. On the basis of the presence of strong Li I $\lambda 6707$ absorption, spectral type later than F0 and chromospheric emission, 112 new weak-line T Tauri stars could be found. We present coordinates, X-ray count-rates and finding charts of the new PMS. Optical UB_V(RI)_{KC}, near-infrared JHKLM and uvby- β photometry for the new WTTS is also provided. In addition 24 dKe-dMe stars were also found on the basis of the RASS data.

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A Parsec Scale Herbig-Haro Jet in Barnard 5

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We report the discovery of a parsec scale jet-like bipolar Herbig-Haro flow, HH 366, emerging from the young stellar object IRS 1 embedded in the dark cloud Barnard 5 (B5) at the eastern end of the Perseus molecular cloud complex. The jet is about 22' in extent which corresponds to a projected length of about 2.2 pc (assuming a distance of 350 pc) and is less than 1' (0.1 pc) wide. The brighter southwestern end of the jet is receding with a velocity between 30 and 100 km/s. The fainter eastern lobe is blueshifted with a slightly lower radial velocity amplitude. The blueshifted jet emerges from IRS 1 at a position angle of about 75°. Both the redshifted and blueshifted portions of the flow are brightest at their ends (the most distant points from the source). In the blueshifted eastern lobe, faint emission can be traced to within several arc minutes of the source while the redshifted lobe emerges from behind the cloud core about 5' southwest of IRS 1.

The orientation and kinematics of the Herbig-Haro jet matches that of the inner portion of the CO outflow from IRS 1 mapped at high angular resolution by Fuller et al (1991). A re-analysis of the Goldsmith et al. (1986) ^{12}CO data shows that an envelope of high velocity molecular gas extends from IRS 1 to both the eastern and western ends of the Herbig-Haro jet. The redshifted lobe of CO emission lying several arc minutes north of IRS 3 (an infrared source located about $10'$ to the southwest of IRS 1) coincides with the southwestern (redshifted) optical lobe of the B5 jet. Although previously associated with IRS 3, this lobe is the brightest portion of the southwestern lobe of the IRS 1 CO outflow. Both the CO flow and the HH jet are nearly orthogonal to a 0.06 parsec long ridge or extended “pseudo-disk” of dense molecular gas seen in tracers such as HCN. The two lobes of the IRS 1 optical outflow are misaligned; the redshifted lobe appears to be deflected south with respect to the axis inferred by connecting B5 IRS1 to the end of the blueshifted lobe. A roughly 5 to 10 km/s motion of the source with respect to the host cloud could produce this misalignment. The IRS 1 outflow provides evidence for outflow models in which CO is entrained from dense molecular gas by a hypersonic jet.

B5 IRS 1 powers a parsec scale bipolar outflow and Herbig-Haro jet. This is one of the first examples of such a giant flow from a low mass young stellar object.

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HST Observations of the Disk and Jet of HH 30

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HH 30 in Taurus has been imaged with the Hubble Space Telescope WFPC2. The images show in reflected light a flared disk with a radius of about 250 AU that obscures the protostar. The disk resembles detailed accretion disk models which constrain its density distribution, and show that its inclination is less than 10 degrees. There are bipolar emission line jets perpendicular to the disk - a very clear demonstration of the standard paradigm for accretion disk and jet systems. However, asymmetries in the light distribution show that the disk has not completely settled into a quasi-equilibrium accretion state, or that some of the observed scattering is from an asymmetric envelope. The emission line jet itself is resolved into a number of knots with typical length and separation of 0.4 arcseconds - much smaller and more numerous than indicated by lower resolution ground-based studies. There are indications of still finer structures in the jet all the way to the resolution limit of 0.1 arcseconds. The knots have proper motions ranging from 100-300 km/sec and are therefore generated at the surprisingly high rate of 0.4 knots/jet/year. The jet appears to be collimated within a cone of opening angle 3 degrees and can be seen to within 30 AU of the star.

Both single and multiple scattering disk models have a range of possible solutions but by requiring pressure support and temperature equilibrium, a self-consistent model emerges. There is evidence for pressure support because the disk appears to have a Gaussian height profile. The temperature at each point in the disk is determined by the disk geometry, which in turn fixes the temperature in a self-consistent manner. The extinction to the protostar is unknown, but constrained to be greater than 24 magnitudes. The optical properties of the scattering grains in the disk are determined and found to imply a large scattering asymmetry, but seem to follow the interstellar reddening law. The absolute magnitude and colors of the unseen protostar are obtained, which has a brightness in the I band of

about 0.16 times solar, and is very red. The disk mass is about 0.006 times solar, and has an expected lifetime of 10^5 years.

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Exact, Algebraic Solutions of the Thin Shell Two-Wind Interaction Problem

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We have developed a formalism based on considerations of linear and angular momentum conservation for solving axisymmetric, steady, “thin shell” problems, which is applicable to problems of interactions of non-accelerated flows. This formalism yields a system of algebraic equations that can be solved to obtain the shape of the thin shell, its mass surface density, and the velocity along the shell. We first use this approach to obtain the solution (obtained with a somewhat different approach by Wilkin 1996) to the problem of an isotropic stellar wind interacting with a plane-parallel stream. Secondly, we find an exact (implicit) and approximate (explicit) analytic solution to the problem of the interaction of two isotropic stellar winds.

Our solution of the two-wind problem is a step forward from previous, numerical solutions based on a ram pressure balance argument, as it is analytic, and furthermore includes centrifugal effects. This solution has clear applications to problems of interacting winds in binary stars, as well as in young stellar objects.

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Preprints also available from www site <http://astro.berkeley.edu/wilkin/franksworld.html>

Compact outflows associated with TMC1 and TMC1A

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High spatial resolution observations are presented of the compact outflows associated with the young protostars TMC1 (IRAS 04381+2540) and TMC1A (IRAS 04365+2535) in Taurus. Emission in CO(1–0) imaged with the Owens Valley millimeter array shows the outflow lobes to be conical close to the star. Analysis of the outflow dynamics indicates that these objects are low-luminosity versions of the energetic outflows more commonly observed. Near-infrared images at H and K show a close correspondence between reflection nebulosity and the location of high-velocity gas, and suggest the outflow cavity is evacuated, as do position-velocity diagrams of the CO(2–1). Comparison of the $J=1-0$ transition with emission in the 2–1 line indicates that the excitation temperature in the high-velocity gas is higher than the surrounding Taurus cloud. We place limits on the inclination of both objects by comparing the data with theoretical outflow models, and conclude that $i \sim 40-70^\circ$ for both objects. The deprojected opening angles of the outflow cones are then in the range $30-40^\circ$.

None of the current outflow models satisfactorily explains the results for TMC1 and TMC1A, which are among the youngest Class I sources in Taurus. We find their outflow structure shares many similarities with the more obscured and possibly younger Class 0 objects, B335 and L1448-C. The main difference is the lower mechanical luminosities of the TMC1 and TMC1A outflows, reflecting a factor of 3–4 smaller linear extent and velocity, and factor of 10–20 lower mass than the L1448-C molecular jet source. Taken together, the four protostars share the common properties of 1) conical outflow lobes close to the star, 2) evacuated outflow cavities, and 3) relatively wide $30-45^\circ$ opening angles. A successful theory of young stellar outflows must be able to explain these characteristics.

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Magnetically-driven jets from Keplerian accretion discs

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Non-relativistic, magnetically-driven jets are constructed by taking self-consistently into account the feedback on the underlying accretion disc. It is shown that such jets are mostly described by the ejection index $\xi = d \ln \dot{M}_a / d \ln r$, which is a local measure of the disc ejection efficiency. This parameter is found to lie in a very narrow range, due to constraints imposed by both the disc vertical equilibrium and the steady transfer of angular momentum.

The investigation of global disc-jets solutions provided two important results. First, it shows that the disc vertical equilibrium imposes a minimum mass flux ejected. Thus, one cannot construct jet models with arbitrarily small mass loads. Second, their asymptotic behaviour critically depends on a fastness parameter $\omega_A = \Omega_* r_A / V_{Ap,A}$, ratio of the field lines rotation velocity to the poloidal Alfvén velocity at the Alfvén surface. This parameter must be bigger than, but of the order of, unity.

Self-similar jets from Keplerian discs, after widening up to a maximum radius whose value increases with ω_A , always recollimate towards the jet axis, until the fast-magnetosonic critical point is reached. It is doubtful that such solutions could steadily cross this last point, the jet either ending there or rebounding. Recollimation takes place because of the increasing effect of magnetic constriction. This systematic behaviour is due to the large opening of the magnetic surfaces, leading to such an efficient acceleration that matter always reaches its maximum poloidal velocity. This “over-widening” stems from having the same ejection efficiency ξ in the whole jet.

Realistic jets, fed with ejection indices varying from one magnetic surface to the other, would not undergo recollimation, allowing either cylindrical or parabolic asymptotic collimation. The study of such jets requires full 2-D numerical simulations, with proper boundary conditions at the disc surface.

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Preprints are available at the SISSA server (<http://babbage.sissa.it>, July 1996 astrophysics archive).

IRAS Observations of the Outer Galaxy I: Discrete Sources and Large Scale (Diffuse) Emission

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The infrared emission in two fields of the outer Galaxy is analyzed using the IRAS image data. We present a census of discrete (but extended) IRAS sources, identified from the 60 micron images. This sample can be used to characterize the properties of typical star forming regions.

We distinguish class A sources (Galactic star forming regions) from other Galactic objects on the basis of their flux density distributions. However, our class A sources have different infrared colors than other star formation groups (YSO's and ultracompact HII regions), as measured by the IRAS Point Source Catalogue. The class A colors, in particular the high 12 micron/ 25 micron ratio, are similar to the color sequence found by Boulanger et al. (1988) for the O-star excited California Nebula. They are also similar to the colors measured, on IRAS image products, for larger “classical” HII regions embedded in large molecular clouds (Chen and Fich 1995). The similar infrared colors suggest that most Class A sources are larger, lower-density regions that sample a variety of local radiation field strengths.

The infrared colors of class A sources are also found to match the colors of normal spiral galaxies. This suggests a close correspondence exists between the physical conditions in outer Galaxy star forming regions and normal spiral galaxies.

The discrete sources have been carefully measured on IRAS Coadd images and detailed comparisons are made with the results from other IRAS data products, especially with the Point Source Catalog (PSC). Great care has been taken

to investigate the uncertainties associated with these measurements and these results may be useful for other studies that make use of IRAS image products.

Information from these measurements are combined with larger scale IRAS images to investigate the relative contributions of different components of the outer Galaxy to the total mid and far-infrared emission. At 60 and 100 microns the diffuse emission (i.e. infrared cirrus) dominates the emission from the discrete sources, which include all possible sites of star formation.

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Hydrodynamical Models of Outflow Collimation in YSOs

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In this paper we explore the physics of time-dependent hydrodynamic collimation of jets from Young Stellar Objects (YSOs). Using parameters appropriate to YSOs we have carried out high resolution hydrodynamic simulations modeling the interaction of a central wind with an environment characterized by a toroidal density distribution which has moderate opening angle of $\theta_\rho \approx 90^\circ$. The results show that for all but low values of the equator to pole density contrast the wind/environment interaction produces strongly collimated supersonic jets. The jet is composed of shocked wind gas. Using analytical models of wind blown bubble evolution we show that the scenario studied here should be applicable to YSOs and can, in principle, initiate collimation on the correct scales ($R \approx 100$ AU). Comparison of our simulations with analytical models demonstrates that the evolution seen in the simulations is a mix of wind-blown bubble and jet dynamics. The simulations reveal a number of time-dependent non-linear features not anticipated in previous analytical studies. These include: a prolate wind shock; a chimney of cold swept-up ambient material dragged into the bubble cavity; a plug of dense material between the jet and bow shocks. We find that the collimation of the jet occurs through both de Laval nozzles and focusing of the wind via the prolate wind shock. Using an analytical model for shock focusing we demonstrate that a prolate wind shock can, by itself, produce highly collimated supersonic jets.

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This paper may be obtained at <ftp://s1.msi.umn.edu/pub/afrank/SFIC1/SFIC.tar.gz>

Evaporation of star-grazing bodies in the vicinity of UX Ori-type stars

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This paper studies the behaviour of star-grazing planetesimal bodies in the neighbourhood of UX Ori-type stars. When approaching a star, large size bodies (diameters of ten meters or more) disintegrate into a number of small fragments under the effect of thermal stresses. In turn, the fragments sublimate within a sphere of about ten stellar radii and form a circumstellar gas envelope.

An important feature of this envelope is a strong excess of heavy elements. Our calculations show that the radiative force on the metal-enriched gas is much larger than in the case of standard chemical composition and exceeds by few times the gravity of the star. As a result, the evaporated matter is accelerated outward and is expelled from the system by radiative pressure.

Thus, the evaporation of planetesimals in the vicinity of young stars leads to complex gas motions which include infall, quasi-keplerian rotation and the radial outflow typical of radiatively driven stellar winds.

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Application of Principal Component Analysis to Large Scale Spectral Line Imaging Studies of the Interstellar Medium

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The multivariate statistical technique of principal component analysis (PCA) is described and demonstrated to be a valuable tool to consolidate the large amount of information obtained with spectroscopic imaging observations of the interstellar medium. Simple interstellar cloud models with varying degrees of complexity and gaussian noise are constructed and analyzed to demonstrate the ability of PCA to statistically extract physical features and phenomena from the data and to gauge the effects of random noise upon the analysis. Principal components are calculated for high spatial dynamic range ¹²CO and ¹³CO data cubes of the Sh 155 (Cep OB3) cloud complex. These identify the 3 major emission components within the cloud and the spatial differences between ¹²CO and ¹³CO emissions. Lower order eigenimages identify small velocity fluctuations and therefore, provide spatial information to the turbulent velocity field within the cloud. A size line width relationship $\delta v \sim R^\alpha$, is derived from spatial and kinematic characterizations of the principal components of ¹²CO emission from the Sh 155, Sh 235, Sh 140, and Gem OB1 cloud complexes. The power law indices for these clouds range from 0.42 to 0.55 and are similar to those derived from an ensemble of clouds within the Galaxy found by Larson (1981) and Solomon (1987). The size line width relationship *within* a given cloud provides an important diagnostic to the variation of kinetic energy with size scale within turbulent flows of the interstellar medium.

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<http://www-fcrao.phast.umass.edu/>

The IRS 1 Circumstellar Disk, and the Origin of the Jet and CO Outflow in B5

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We report the discovery of the inner edge of the high velocity CO outflow associated with the bipolar jet originating from IRS 1 in Barnard 5 and the first ever resolution of its circumstellar disk in the 2.6 mm dust continuum and C¹⁸O. From high spatial resolution observations made with the Owens Valley Millimeter Array we are able to locate the origin of the outflow to within ~ 500 AU on either side of IRS 1 and apparently at the edge of, or possibly within, its circumstellar disk. The orientation of the continuum disk is perpendicular to the highly collimated jet outflow recently seen in optical emission at much further distances. The disk has been detected in C¹⁸O giving a disk mass $\sim 0.16 M_\odot$. Our HCO⁺ and HCN maps indicate significant chemical differentiation in the circumstellar region on small scales with HCO⁺ tracing an extended disk of material. The ¹²CO interferometer maps of the outflow show two cone-like features originating at IRS 1, the blue one fanning open to the northeast and the red one to the southwest. The vertices of the cones are on either side of the circumstellar disk and have a projected opening angle of about 90°. The intrinsic opening angle is in the range of 60° to 90° which leads to significant interaction between outflow and infall.

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Angular momentum transfer in pre-main-sequence stars of intermediate mass

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Pre-main-sequence stars between 2 and 5 M_{\odot} (Herbig Ae/Be stars) possess strong stellar winds and extended chromospheres. The non-radiative heating necessary to fuel such chromospheres is considerable. Unlike solar type stars, this heating can not be related to the existence of a subphotospheric convection zone, as their envelope are in radiative equilibrium. Another possibility advanced for T Tauri stars is to use the gravitational energy contained in an accretion disk; however, the presence of optically thick disks around Herbig Ae/Be stars has been seriously questioned recently. The kinetic energy of stellar rotation is potentially sufficient to support this chromospheric heating during the evolution towards the main-sequence. The problem is to find an efficient mechanism to extract rotational energy, to transfer and dissipate it in the outer layers of the star. We investigate the effect of the angular momentum losses driven by a strong stellar wind on the distribution of the angular momentum inside the star. We propose that the braking torque exerted by the wind forces turbulent motions below the stellar surface. Guided by an analogy with geophysical and experimental fluids, a simplified model shows that the wind-induced angular momentum losses are efficiently transferred through the stellar interior by these turbulent motions. This transfer occurs in a turbulent layer which deepens towards the stellar interior in a time-scale of 10^6 years, comparable with the Kelvin time-scale of Herbig Ae/Be stars. It results that, during their pre-main-sequence evolution, Herbig Ae/Be stars convert part of their rotational energy into turbulent motions. This provides appropriate physical conditions to produce a magnetic field which could transfer and dissipate this turbulent kinetic energy in the outer layers of the star.

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44 GHz Methanol Masers and Quasi-Thermal Emission in Sagittarius B2

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The Very Large Array has been used to obtain $\sim 3''$ resolution observations on the 44 GHz $7_0 \rightarrow 6_1 A^+$ transition of CH₃OH (methanol) in the Sgr B2 massive star-forming complex. A total of 18 compact regions showing maser emission are found, which are spread over a 2.1 pc \times 4.3 pc ($\alpha \times \delta$) region. Many of these are offset far from known molecular cores and ultracompact HII regions and may trace the interaction region of a cloud-cloud collision. There is no spatial coincidence between 44 GHz and 6.7 GHz CH₃OH masers in this region, as expected because the pumping mechanisms for these two transitions are different. Isotropic maser luminosities range between 1×10^{-6} and 2.1×10^{-5} L_{\odot} . In addition, 17 regions with broad-linewidth quasi-thermal 44 GHz CH₃OH emission are identified, many of which are close to known molecular hot cores, in particular those associated with the Sgr B2(N) and Sgr B2(M) continuum sources. In Sgr B2(N), quasi-thermal emission appears to be associated with two $10''$ diameter ionized shells. These ionized shells may have swept up and shocked molecular material as they expanded. Also, a quasi-thermal core is observed to be coincident with a source of continuum emission from dust and emission from more complex species. In Sgr B2(M), CH₃OH quasi-thermal emission arises predominately from the western portion of this region. The CH₃OH fractional abundance in most of the quasi-thermal cores appears to be quite high at $\sim 10^{-6}$. It is argued that grain-surface chemistry is responsible for this high abundance.

Preprints available at <ftp.astro.uiuc.edu:/pub/dmehring/sgrb2/preprint.tar.gz>

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Are Both Stars in a Classic T Tauri Binary Classic T Tauris ?

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Large near IR color excesses and emission line spectra indicate the presence of optically thick circumstellar accretion disks and active boundary layers in young stars. We investigate whether this classic T Tauri (TT) behavior is found in one or both members of a binary system previously identified as a TT on the basis of the unresolved light. We consider the angularly resolved Br γ and, in one case, Na I, spectra of four close (1.3-2.6'') TT systems. We also take into account the angularly resolved near IR (K-L) colors of eight additional young binaries with separations between

0.3'' and 2.5''. We find that for all twelve systems, both components show, or have shown in the history of their observation, evidence for classic T Tauri behavior. We demonstrate that this cannot be the result of random pairing of a population of single TT and weak-lined T Tauri (WT) stars. We speculate that the result that inner, AU-sized disks tend to survive for a similar length of time in both components of a close (0.3-2.6'') binary suggests that a circumbinary envelope effectively regulates the common evolution of the inner disks.

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HST Observations of Jets from Young Stars

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We report on Hubble Space Telescope (HST) emission line ([SII] $\lambda\lambda$ 6716,6731, H α , [OI] λ 6300 and nearby continuum imaging) of the HL Tau and HH 30 jets from our own HST program as well as a study of HST Archive [SII] $\lambda\lambda$ 6716,6731 images of the HH 1 and HH 34 jets. It is found in all cases that these jets are well-resolved in the lateral direction (with FWHM diameters $\geq 0.2''$) as far as we can follow them to their source which, in the case of HH 30, is as close as 0.25'' (35 AU). Assuming the jet has essentially zero angular width at its origin, one can deduce a *lower bound* for the initial opening angle and the values obtained are very large indeed (e.g. $\geq 60^\circ$ for the HH 30 jet and counterjet). Our data are shown to support models in which the jet is initially poorly focused before being asymptotically collimated into a ‘‘column’’ with a diameter of order a few tens of AU. As regards the origin of the knots seen in these jets, it is found that many of the knots in the HH 1 and HH 34 jets resemble internal bow shocks, at least far away from their driving source $\geq 5''$ and $10''$ in the case of HH 1 and HH 34 jets respectively). This is consistent with models in which the knots are attributed to ‘‘internal working surfaces’’ caused by temporal variations in the outflow from the source. It is found in the case of the HH 30 jet, however, that its knots, at least close to the source, might have another origin. Accepted by Ap. J. Letters

Preprint at <http://www.cp.dias.ie/astro/preprints>

Imaging of an infalling disk-like envelope around L1551-IRS 5

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Aperture synthesis observations of H¹³CO⁺ (J=1-0) emission from L1551-IRS 5 were made using the Nobeyama Millimeter Array. It is found that the emission has a disk-like structure with a size of 5600 \times 2800 AU at P.A. = 160°. If we assume a geometrically thin disk, its radius and inclination angle is estimated to be 2800 AU and 60° (= $\cos^{-1}(2800/5600)$), and the disk major axis is almost perpendicular to the molecular outflow. It is noted that there exists radial motion, i.e., velocity gradient along the disk minor axis in the inner region ($r < 1000$ AU). The motion can be interpreted as infalling motion, because the blueshifted emission is located on the far side of the disk and the redshifted one on the near side by considering the geometrical relation between the H¹³CO⁺ feature and the bipolar outflow. The infalling velocity corrected for the inclination is estimated to be 0.6 km s⁻¹ at $r = 800$ AU and is smaller than the free-fall velocity (~ 1.5 km s⁻¹ at $r = 800$ AU) with a stellar mass of 1 M_⊙. The H₂ mass of the disk and the mass infall rate are estimated to be 0.27 M_⊙ and $\sim 1.1 \times 10^{-5}$ M_⊙ yr⁻¹, respectively. In addition to the infalling motion, the molecular emission also has a velocity structure along the major axis, suggesting rotating motion. The rotational velocity corrected for the inclination is estimated to be 0.23 km s⁻¹ at $r = 900$ AU, which is smaller than Keplerian rotational velocity, suggesting that the envelope is not rotationally supported. The H¹³CO⁺ disk-like structure would be a disk-like infalling envelope around L1551-IRS 5.

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Multi-dimensional numerical simulations of molecular jets

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Molecular jets announce the successful birth of a protostar. We develop here a model for the jets and their environments, adapting a multi-dimensional hydrocode to follow the molecular-atomic transitions of hydrogen. We examine powerful outflows into dense gas. The cocoons which form around the jet are very low density cavities of atomic gas. These atoms originate from strong shocks which dissociate the molecules. The rest of the molecules are either within the jet or swept up into very thin layers. Pulsed jets produce wider cavities and molecular layers which can grow onto resolvable jet knots.

Three-dimensional simulations produce shocked molecular knots, distorted and multiple bow shocks and arclike structures. The resemblance of simulated images of the 1-0 S(1) H₂ emission to recently observed deeply embedded outflows in HH211, HH212, HH288 and L1634 is discussed. Spectroscopic and excitation properties of the hydrogen molecules and CO maps are calculated. In the infrared, strong emission is seen from shocks within the jet (when pulsed) as well as from discrete regions along the cavity walls. Excitation, as measured by line ratios, is not generally constant. Broad double-peaked, shifted emission lines are predicted. Low-J CO emission is limb-brightened but spread over the whole outflow region. Some of these signatures are shown to depend on the chosen jet conditions.

We find that three-dimensional calculations are essential for numerical simulations of strong cooling jets.

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Influence of cooling-induced compressibility on the structure of turbulent flows and gravitational collapse

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We investigate the properties of highly compressible turbulence, the compressibility arising from a small effective polytropic exponent γ_e due to cooling. In the limit of small γ_e , the density jump at shocks is shown to be of the order of e^{M^2} . Without self-gravity, the density structures arising in the moderately compressible case consist mostly of patches separated by shocks and behaving like waves, while in the highly compressible case clearly defined long-lived object-like clouds emerge. When the forcing in the momentum equation is purely compressible, the rotational energy decays monotonically in time, indicating that the vortex-stretching term is not efficient in transferring energy to rotational modes. This property may be at the origin of the low amount of rotation found in interstellar clouds. Vorticity production is found to rely heavily on the presence of additional terms in the equations. In the presence of self-gravity, we suggest that turbulence can produce bound structures for $\gamma_e < 2(1 - 1/n)$, where n is the typical dimensionality of the turbulent compressions. We support this result by means of numerical simulations in which, for sufficiently small γ_e , small-scale turbulent density fluctuations eventually collapse even though the medium is globally stable. This result is preserved in the presence of a magnetic field for supercritical mass-to-flux ratios. At larger polytropic exponents, turbulence alone is not capable of producing bound structures, and collapse can only occur when the medium is globally unstable. This mechanism is a plausible candidate for the differentiation between primordial and present-day stellar-cluster formation and for the low efficiency of star formation.

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Postscript file and related mpeg simulations available at http://www.astroscu.unam.mx/turbulence/turbulence_HP.html

The formation and evolution of low mass protostars

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A description is presented of the earliest stages of protostellar evolution. Observations of pre-stellar cores, which are believed to represent the initial conditions for protostellar collapse, depart significantly from the scale-free density distribution which is usually taken as the starting point for the formation of a low-mass protostar. Pre-stellar cores are observed to have radial density profiles which have flat inner regions, steepening towards their edges. This is seen to qualitatively match the predictions of the Bonnor-Ebert stability criterion for pressure-bounded self-gravitating gas clouds. From these initial conditions, theoretical modelling of cores threaded by magnetic fields predicts that quasi-static evolution by the process of ambipolar diffusion will lead to a significantly different starting point for collapse than the static singular isothermal sphere.

This departure from a scale-free density distribution for the initial conditions has recently been shown to produce an ensuing protostellar collapse which has a non-constant accretion rate. Recently published observations of low-mass protostars in the ρ Ophiuchi cluster are demonstrated to be consistent with such a non-constant protostellar mass accretion rate, contrary to the standard protostellar collapse model. Instead, the data appear consistent with an initially high accretion rate, which subsequently decays. The initial phase of high accretion rate is labelled the '*main accretion phase*', during which ≥ 50 per cent of the circumstellar envelope mass is accreted in ~ 10 per cent of the total accretion time, and which is equated observationally with Class 0 objects. The subsequent phase with roughly an order of magnitude lower accretion rate is labelled the '*late accretion phase*', during which the remainder of the envelope mass is accreted in the remaining ~ 90 per cent of the total accretion time, at an order of magnitude lower accretion rate, and which is equated observationally with Class I objects. The growth of circumstellar discs begins in the Class 0 stage, and proceeds through the Class I & II stages. Published data of the Taurus star-forming region currently available appear also to be consistent with this scenario.

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Preprints available at <http://www.roe.ac.uk/>

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, where you can access it via the ESO Portal (<http://http.hq.eso.org/eso-homepage.html>). You can also access it through the University of Massachusetts Astronomy World Wide Web server, the URL for its home page is <http://www-astro.phast.umass.edu/>

Dissertation Abstracts

A Multiwavelength Study of the Process of High-Mass Star Formation

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Massive stars live short, violent lives that have a major impact on nearby star formation and the interstellar medium (ISM). To study the process of high-mass star formation and its effect on the surrounding ISM, we have observed four regions that include 10 HII regions representing ultracompact, compact, and nearly classical HII regions: Monoceros R2; K3-50; S255-2; and NS 14. Exciting stars of the 10 HII regions span a range of masses (B1 to O4 type stars). We have placed the objects in an evolutionary sequence with K3-50A, C1, and C2 representing the earliest, ultracompact HII region stage, S255-2 and NS 14 representing an intermediate compact stage, while MonR2, K3-50B and K3-50D are more evolved, representing a nearly classical HII region stage.

The process of high-mass star formation does not have a well developed theoretical basis, in part, because many complete observational studies of such regions have not been made. Toward this end, we have obtained extensive infrared images of each region mentioned above with near-infrared (NIR) broadband filters and narrow band (1-2% spectral resolution) circular variable filters (CVFs). These are complemented by radio wavelength continuum and millimeter wavelength molecular aperture synthesis observations.

Massive stars spend $\geq 10\%$ of their lives embedded in molecular clouds and are generally enshrouded in gas and dust when they reach the main-sequence. To account for this, we have mapped dust extinction on small spatial scales and compared these maps with dense molecular gas structures. These comparisons yield mass and molecular abundance estimates. Massive toroidal clouds are found in each region and may be ubiquitous features. Such toroidal clouds may provide the collimation necessary to form jets from strong stellar winds. Bipolar ionized outflows or jets appear well correlated with evolutionary stage, with the youngest objects producing the strongest jets. The jets appear to entrain molecular material, thereby powering bipolar outflows which last $> 1.5 \times 10^5$ yrs.

Detailed analyses of the four individual regions, including population studies of associated stellar cluster members, are made and a general picture of the process of high mass star formation is presented including: triggered formation of toroidal (proto-cluster) cloud core(s); fragmentation of the core(s) and formation of high-mass protostar(s), ultracompact HII region(s) and associated stellar cluster(s); and evolution of outflows from bipolar ionized jets to massive, extended molecular outflows.

Meetings

Star Formation with the Infrared Space Observatory (ISO)

24 – 26 June 1997 Lisbon, Portugal

Hosted by:

Faculdade de Ciências da Universidade de Lisboa

Fundação Calouste Gulbenkian

General Information

ISO, the *Infrared Space Observatory*, is giving us access, with unprecedented sensitivity and resolution, to a range of wavelengths in which it is extremely important to observe, in order to study the physical processes taking place during the star formation process: those between about 2.5 and 240 μm (where the earth atmosphere is mostly opaque and embedded YSOs emit most of their energy). Equipped with its four instruments: the photometer (PHT), the camera (CAM), the short-wavelength spectrometer (SWS), and the long-wavelength spectrometer (LWS), it is opening the perspective of new discoveries and the possibility of answering further the central question “How do stars form?” In addition, ISO will certainly reveal much about the structure and properties of the interstellar medium in its relationship with the phenomenon of star formation. It is expected, therefore, that this conference will be a major contribution to a growing understanding of the process of star formation.

The purpose of this conference is to offer an opportunity for the different specialists in Star Formation, who have used ISO, to get together and present and exchange their results. Given the exciting new discoveries expected to be yielded by the ISO mission in this field, we believe this meeting can play an important role in disseminating the ISO results in this field. As usual, much insight into the science can be gained by cross-fertilization of ideas in a meeting of this kind.

The Workshop is organized by the Faculdade de Ciências da Universidade de Lisboa (University of Lisbon), and will take place in Lisbon from the 24th to the 26th June 1997. Due to space restrictions, attendance will be limited. For further information, this conference will have a WWW page which is currently under construction. It will be located at the following address: <http://astro.cc.fc.ul.pt/iso/iso.html>.

Those intending to participate are requested to manifest their intention by sending a message to the following e-mail address: iso@astro.cc.fc.ul.pt. The message should contain: name, address, e-mail address, and tentative title of talk. They will receive all announcements that will be issued.

Preliminary Scientific Program

The topics of the meeting include:

Physics and Chemistry of the Interstellar Medium
ISO surveys of nearby SFRs (star forming regions) and embedded stellar populations
Dense Cores and Protostars
Circumstellar Disks: Properties and Evolution
Interaction of YSOs with the ISM: jets and outflows
Massive Star Formation
Star Formation in Nearby Galaxies

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