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Abstracts of recently accepted papers

Forbidden lines from T Tauri disk winds. I. High magnetic torque models

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We present synthetic emission maps and long-slit spectra in the [O I]6300 and [S II]6731 lines for self-similar, cold MHD disk winds of high magnetic torque. We find that such models produce both a dense, compact low-velocity component (LVC) and a lower density, collimated high-velocity component (HVC) sharing several observed properties of jets from T Tauri stars (resolved transverse sizes, strong apparent acceleration in [O I], larger spatial displacement and lower gradients in [S II]). Hence, the LVC and HVC observed in TTS might be formed in two distinct regions of the same wind. We suggest that disk wind models with lower ratio of magnetic to viscous torque and significant heating at the wind base could compare even more favorably with the observations.

Accepted by Astronomy & Astrophysics Letters

Short-term spectroscopic variability in the pre-main sequence Herbig Ae star AB Aur during the MUSICOS 96 campaign

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We present results of the spectroscopic monitoring of AB Aur obtained during the MUSICOS 96 campaign. The analysis is mainly focussed on the He I D3 line, on the H α line, and on a set of photospheric lines. The star was monitored irregularly for more than 200 hours.

We confirm the high level of variability of spectral lines in AB Aur. We find that the photospheric lines have a profile differing significantly from a classical rotational profile. The dominant features of this abnormal photospheric profile are a blue component, in absorption, whose velocity is modulated with a 34hr period, and a red component, stable in velocity but of variable intensity, with a possible periodicity near 43 hrs.

The He I D3 line exhibits two well-defined components: a blue component, always in emission with a velocity modulated with a 45hr period, and a red component of variable intensity, alternatively in emission and in absorption, occurring at a fixed velocity, with a variable intensity possibly modulated with a 45 hr period.

The H α line, showing a P Cygni profile, also exhibits pseudo-periodic variations of its blue absorption component, but its variability appears more complicated than that of the other lines studied here.

We suggest that the blue component of the photospheric lines is modulated by the star's rotation, with a period of 34 hrs, due to a highly inhomogeneous photosphere, involving significant radial flows. Our model also involves downflows onto the stellar pole to account for the red components of the photospheric lines and of the He I D3 line.

We propose two different interpretations of the behavior of the blue component of the He I D3 line. In the first one, this component is formed in a wind originating from the star's equatorial regions. In this interpretation, the rotation period of the equatorial regions of the star is 45 hrs, implying a 25% surface differential rotation, with the pole rotating faster than the equator. The second interpretation involves a wind originating from a region of a circumstellar disk, at a distance of 1.6 stellar radii from the star's center, with a rotation period of 45 hrs. We are not able to decide which one of these two interpretations is more likely, on the basis of the data presented here.

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<http://www.obs-mip.fr/omp/umr5572/magnetisme/publcatala.html>

or

<http://www.obs-mip.fr/omp/umr5572/magnetisme/abaur96.ps.gz>

High density molecular clumps around protostellar candidates

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There are several indications that strong H₂O maser emission arises at the very beginning of the evolution of a massive star and disappears when an HII region becomes detectable in the radio continuum. If this is the case, one expects to find dense hot molecular gas surrounding embedded far IR sources coincident with H₂O masers. In order to test this hypothesis, we have used the Pico Veleta 30-m radiotelescope to search for molecular line emission towards a sample of 12 H₂O masers located in regions of massive star formation, but *not* directly associated with bright compact radio HII regions, with the intention to identify the sites of newly born massive (proto)stars in their *earliest* stages and to study their properties.

Our main goals were: a) to confirm the hypothesis that the H₂O masers not associated with compact radio continuum emission are indeed located at the centre of high density clumps within a molecular cloud; b) to use several molecular transitions (namely: ¹³CO(2-1), CS(3-2), C³⁴S(2-1), C³⁴S(3-2), C³⁴S(5-4), HCN(1-0), CH₃CN(8-7), CH₃CN(12-11), HCO⁺(1-0), CH₃OH(3-2), CH₃OH(5-4)) in order to derive information on the size, kinematics, temperature, density, and ionisation degree of the molecular gas in the places where star formation has just begun, as well as to search for the presence of outflows on scale sizes of 10''-30''.

In this paper we present the large amount of data obtained at Pico Veleta in a compressed way, but still sufficiently ample to give usable informations for further studies. General results from a first analysis of the data are also presented.

Our first goal is amply verified since in all cases and in molecules tracing high density gas we find a barely resolved peak at the position of the maser, confirming the validity of our selection criteria. Our sample thus provides a valid

reference list of regions of massive star formation in their earliest phases.

As far as the second goal is concerned, the large variety of intensity ratios of different molecules, as well as of other derived parameters, point out that the molecular clumps where star formation is taking place are far from identical and that chemical evolution and influence of the newborn star may amply affect the line intensity ratios.

In some cases small scale (seconds of arc) outflows were detected, not necessarily related to the minute of arc scale outflows present in the same regions.

More detailed studies of each region are presented in separate papers.

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

Magnetic Fields in Molecular Clouds - Observations Confront Theory

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This paper presents a summary of all 27 available sensitive Zeeman measurements of magnetic field strengths in molecular clouds together with other relevant physical parameters. From these data input parameters to magnetic star formation theory are calculated and predictions of theory are compared with observations. Results for this cloud sample are: (1) Internal motions are supersonic but approximately equal to the Alfvén speed, which suggests that supersonic motions are likely MHD waves; (2) The ratio of thermal to magnetic pressures $\beta_p \approx 0.04$, implying that magnetic fields are important in the physics of molecular clouds; (3) The mass-to-magnetic flux ratio is about twice critical, suggesting but not requiring that static magnetic fields alone are insufficient to support clouds against gravity; (4) Kinetic and magnetic energies are approximately equal, suggesting that static magnetic fields and MHD waves are roughly equally important in cloud energetics; and (5) Magnetic field strengths scale with gas densities as $|\mathbf{B}| \propto \rho^\kappa$ with $\kappa \approx 0.47$; this agrees with the prediction of ambipolar diffusion driven star formation, but this scaling may also be predicted simply by Alfvénic motions. The measurements of magnetic field strengths in molecular clouds make it clear that magnetic fields are a crucial component of the physics governing cloud evolution and star formation.

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Preprints: <http://www.astro.uiuc.edu/preprints/crutcher/>

NGC 3576 and NGC 3603: Two Luminous Southern HII Regions Observed at High Resolution with the Australia Telescope Compact Array

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NGC 3576 (G291.28-0.71; $l = 291.3^\circ$, $b = -0.7^\circ$) and NGC 3603 (G291.58-0.43; $l = 291.6^\circ$, $b = -0.5^\circ$) are optically visible, luminous HII regions located at distances of 3.0 kpc and 6.1 kpc, respectively. We present 3.4 cm Australian Telescope Compact Array (ATCA) observations of these two sources in the continuum and the H90 α , He90 α , C90 α and H113 β recombination lines with an angular resolution of 7'' and a velocity resolution of 2.6 km s⁻¹. All four recombination lines are detected in the integrated profiles of the two sources. Broad radio recombination lines are detected in both NGC 3576 ($\Delta V_{FWHM} \geq 50$ km s⁻¹) and NGC 3603 ($\Delta V_{FWHM} \geq 70$ km s⁻¹). In NGC 3576 a prominent N-S velocity gradient (~ 30 km s⁻¹ pc⁻¹) is observed, and a clear temperature gradient (6000 K to 8000 K) is found from east to west, consistent with a known IR color gradient in the source. In NGC 3603, the H90 α , He90 α and the H113 β lines are detected from 13 individual sources. The Y⁺ (He/H) ratios in the two sources range from 0.08 \pm 0.04 to 0.26 \pm 0.10. The H113 β /H90 α ratio in NGC 3576 is close to the theoretical value, suggesting that local thermodynamic equilibrium (LTE) exists. This ratio is enhanced for most regions in NGC 3603; enhanced β/α ratios in other sources have been attributed to high optical depth or stimulated emission. We compare the morphology and kinematics of the ionized gas at 3.4 cm with the distribution of stars, 10 μ emission and H₂O, OH, and CH₃OH maser emission. These comparisons suggest that both NGC 3576 and NGC 3603 have undergone sequential star formation.

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A Giant Herbig-Haro Flow from a Massive Young Star in G192.16–3.82

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We report the discovery of a 10 pc long Herbig-Haro flow powered by a moderately massive young star associated with the compact HII region G192.16–3.82. At a distance of 2 kpc, the luminosity of G192.16–3.82 is about 3000 L_{\odot} . The HH 396/397 complex consists of a network of filamentary emission line objects that trace a pair of collimated and limb brightened outflow lobes that emerge from an opaque cloud core. The $H\alpha$ and [S II] bright nebulosity has a large area covering factor and extends well beyond the mapped extent of the associated high velocity molecular outflow. The HH 396/397 complex contains some shocks with a surface brightness comparable to HH 168 in Cepheus A, placing these among the brightest known HH objects. Furthermore, a large fraction of a 1 arcmin by 18 arcmin region surrounding G192.16–3.82 is laced with lower surface brightness emission line features, making HH 396/397 one of the most spatially extended HH complexes studied so far. The dynamical age of this outflow is in the range $10^4 - 10^5$ years. We discuss plausible evolutionary scenarios for outflows powered by high mass protostars and argue that the G192.16–3.82 outflow complex is relatively evolved. Despite being very elongated, this HH flow is most likely powered by a moderately collimated wind rather than a highly collimated jet.

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A Giant Herbig-Haro Flow from Haro 6-10

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We report the discovery of a parsec scale Herbig-Haro flow emanating from the young binary system Haro 6-10 in Taurus. The flow extends for about 39 arcminutes (1.6 pc) at a position angle of about 222 degrees and contains part of the previously known HH 184. The apparent ends of the flow are defined by the newly discovered HH 410 and HH 411, which are located 24 arcminutes SW and 15 arcminutes NE, respectively, from Haro 6-10. We suggest that the giant HH flow is most likely driven by the infrared companion to the T-Tauri primary in Haro 6-10, however the T-Tauri component also appears to be driving a relatively weak and much smaller outflow with a N-S orientation. The two flows appear to undergo synchronized episodes of increased mass ejection which may be due to enhanced gravitational interactions between the binary components during periastron. We also report the discovery of a new HH jet, HH 414, which is driven by IRAS 04264+2433. HH 414 points directly towards an associated bow shock, HH 413; the HH 413/414 flow crosses the axis of the HH 410/411 flow at a large angle.

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On the transfer of momentum from stellar jets to molecular outflows

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While it is generally thought that molecular outflows from young stellar objects (YSOs) are accelerated by underlying stellar winds or highly collimated jets, the actual mechanism of acceleration remains uncertain. The most favoured model, at least for low and intermediate mass stars, is that the molecules are accelerated at jet-driven bow shocks. Here we investigate, through high resolution numerical simulations, the efficiency of this mechanism in accelerating ambient molecular gas *without causing dissociation*. The efficiency of the mechanism is found to be surprisingly low suggesting that more momentum may be present in the underlying jet than previously thought. We also compare the momentum transferring efficiencies of pulsed versus steady jets. We find that pulsed jets, and the corresponding steady jet with the same average velocity, transfer virtually the same momentum to the ambient gas. The additional momentum ejected sideways from the jet beam in the case of the pulsed jet only serves to accelerate post-shock *jet* gas which forms a, largely atomic, sheath around the jet beam.

For both the steady and pulsing jets, we find a power law relationship between mass and velocity ($m(v) \propto v^{-\gamma}$) which is similar to what is observed. We also find that increasing the molecular fraction in the jet decreases γ as one might expect. We reproduce the so-called Hubble law for molecular outflows and show that it is almost certainly a local effect in the presence of a bow shock.

Finally, we present a simple way of overcoming the numerical problem of negative pressures while still maintaining overall conservation of energy. Accepted by Astron. Astrophys.

Preprints: http://www.maths.tcd.ie/~tppd/documents/papers/mom_trans.ps.gz

High-Resolution Imaging of Ultracompact HII Regions - II – G5.89-0.39 Revisited

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We present the results of an extensive imaging campaign on the ultracompact HII region G5.89-0.39 at near- and mid-infrared wavelengths. High-resolution data were taken in the H , K' , and L bands using ESO's adaptive optics system ADONIS. They are complemented by conventional narrow-band images in $\text{Br}\gamma$ and $\text{H}_2(1-0)\text{S1}$ as well as by mid-infrared broad- and narrow-band images. We also mapped the 1.3 mm continuum emission from the source using the SEST.

We use our data to consistently explain the morphological appearance of G5.89-0.39 at all observed wavelengths as well as its spectral energy distribution. The complete model of the source consists of a spherical shell of dust with an inner, dust-free cavity of 7.6×10^{16} cm radius surrounding a star of spectral type O6 ZAMS. Two outflows escape this shell in opposite directions. Half of the whole configuration is evidently obscured by a very massive cloud of cold dust. Comparisons with earlier models and other ultracompact HII regions are drawn to put G5.89-0.39 in the context of massive star formation.

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<http://www.astro.uni-jena.de/~mfeldt/g589.ps>

BVRI photometry of the star-forming region NGC 2264: the initial mass function and star-forming rate

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The pre-main sequence (PMS) population in the mass range between ≈ 0.2 and $\approx 3 M_{\odot}$ in southern part of the star-forming region NGC 2264 has been studied, determining both the Initial Mass Function in the region as well as the star-formation rates for different mass ranges. The sample is a composite one, derived through the union of samples obtained through different techniques and each suffering from different biases: previously known PMS stars in the region from the literature, photometrically-selected T Tauri candidates (from our own photometric data, discussed in detail in the present paper) and X-ray selected PMS candidates (discussed in detail in a companion paper) have been joined to form a sample which we show to be statistically complete (i.e. free from the biases which affect each of the parent samples) down to $\simeq 0.6 M_{\odot}$ (while being incomplete at lower masses). Individual masses and ages have been derived by placing the individual stars on evolutionary tracks, allowing us to derive both the IMF and the star formation rate.

The Initial Mass Function thus derived for NGC 2264 shows evidence for a bimodal distribution of masses, with a break in the IMF at around $1 M_{\odot}$.

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http://www.astropa.unipa.it/Library/preprint_opa.html

OH and H₂O masers in 74 star-forming regions - The FC89 database

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Positions and spectra of 1665 MHz OH and 23,235 MHz H₂O masers in 74 star-forming regions are presented. This supplement provides an electronic version of the complete VLA database of interstellar masers observed by Forster & Caswell (1989 A&A, 213, 339). The fields observed comprise the majority of known interstellar OH and H₂O maser associations at galactic longitudes observable from both hemispheres. The database will be useful for interpreting continuum and molecular line observations of these regions, for investigations of the relationship between the masers and their local environment, and for temporal and kinematical studies of the masers themselves.

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Population Diagram Analysis of Molecular Line Emission

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We develop the use of the population diagram method to analyze molecular emission in order to derive physical properties of interstellar clouds. We focus particular attention on how optical depth affects the derived total column density and the temperature distribution. We derive an optical depth correction factor which can be evaluated based on observations, and which incorporates the effect of saturation on derived upper level populations. We present analytic results for linear molecules in *LTE*. We investigate numerically how subthermal excitation influences the population diagram technique, studying how the determination of kinetic temperature is affected when the local density is insufficient to achieve *LTE*. We present results for *HC₃N* and *CH₃OH*, representative of linear and non-linear molecules, respectively. In some cases, alternative interpretations to the standard optically thin and thermalized picture yield significantly different results for column density and kinetic temperature, and we discuss this behavior. The population diagram method can be a very powerful tool for determining physical conditions in dense clouds if proper recognition is given to effects of saturation and subthermal excitation. We argue that the population diagram technique is, in fact, superior to fitting intensities of different transitions directly, and indicate how it can be effectively employed.

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Accretion shocks in T Tauri stars. Diagnosis via semiforbidden UV lines ratios.

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Numerical calculations of the structure of accretion shocks in T Tauri stars (TTs) indicate that the C III]1909, O III]1661+1666 and Si III]1892 ultraviolet lines should have comparable intensities. We show how the density and the velocity of the accreted gas can be derived from these lines ratios. We also indicate how these parameters can be used, together with other less reliable as the distance and the extinction, to derive the accretion rate and the accretion luminosity. It is shown that the lines ratios as well as their absolute fluxes (as measured with the International Ultraviolet Explorer) are in agreement with the predictions of the accretion shock model. However this method is best suited for the analysis of high resolution data (as those obtained with the Hubble Space Telescope) from which accurate fluxes can be determined and blended components (stellar atmosphere, winds) can also be properly subtracted out.

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Temperature predictions for protostellar outflows

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The acceleration mechanism for protostellar outflows is still uncertain, despite many dynamical studies. Active acceleration processes are expected to heat the molecular gas, and it should be possible to choose between the possible outflow models by excitation studies which measure the temperature of the molecular gas. We show how temperature predictions can be made from a simple bow-shock driven shell model and compared with temperature estimates from excitation studies. As the momentum-conserving shell expands the kinetic energy lost is sufficient to heat the molecular gas to temperatures many times that of the ambient cloud. The energy transfer - and therefore the temperature - is greatest near to the bow shock and therefore the temperature rises with distance from the star. We present a multitransition CO study of the young outflow L483 and compare temperature predictions from the shell model with measurements of the CO excitation.

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<http://saturn.phy.umist.ac.uk:8000/jjh/outflow-temp.ps.gz>

WWW database of optical constants for astronomy

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The database we announce contains references to the papers, data files and links to the Internet resources related to measurements and calculations of the optical constants of the materials of astronomical interest: different silicates, ices, oxides, sulfides, carbides, carbonaceous species from amorphous carbon to graphite and diamonds, etc.

We describe the general structure and content of the database which has now free access via Internet:

<http://www.astro.uni-jena.de/Users/database/entry.html> or <http://www.astro.spbu.ru/JPDOC/entry.html>.

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Hubble Space Telescope WFPC2 Imaging of XZ Tauri: Time Evolution of a Herbig-Haro Bowshock

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We report observations of dramatic morphological changes in the extremely young Herbig-Haro object ejected by the pre-main sequence binary XZ Tauri. Hubble Space Telescope images taken in 1995 showed a filled bubble of emission nebulosity extending 4" NNE of the system in the direction of a previously known jet. New images obtained in 1998 show that the bubble has undergone a remarkable transition into a limb-brightened structure as it continues its motion away from the binary. The new images suggest that we are witnessing the initial formation of the post-shock cooling zone in a newly emerging HH bow shock system, probably accompanied by significant temporal evolution in the nebula's emission line spectrum.

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Shocked Molecular Hydrogen from RNO 91

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We report the detection of the H₂ $v=1-0$ S(1) line at 2.122 μ m, from RNO 91 in the L43 dark cloud, which is known to be a T Tauri star surrounded by a 1700AU disk structure (containing ices) and a weak outflow. The non-detection of the H₂ $v=2-1$ S(1) line at 2.247 μ m suggests shock excitation rather than fluorescence. The emission is extended spatially up to 9" in the north-south direction. The line intensity peak (FWHM \sim 3") corresponds to the star RNO 91 which is embedded in a cocoon of gas and dust. The observed H₂ emission from this cocoon may be attributed to embedded Herbig-Haro like knots. The H₂ line flux in the central 2" \times 3" is estimated to be 7×10^{-14} ergs sec⁻¹cm⁻², which indicates a mass flow rate of 4×10^{-8} M_⊙ yr⁻¹. Furthermore, narrow band image taken through H₂ 1-0 S(1) filter is presented, which reveal a tilted disk and bipolar outflow structure that agrees with earlier observations and models. We show that this disk/outflow system is a unique case.

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X-ray emission of an accretion shock in the case of T Tauri stars

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Main characteristics of accretion shock X-ray emission in the case of Classical T Tauri Stars (CTTSs) are considered. It is demonstrated that observed spectrum of the shock is more hard than that of post-shock cooling zone due to absorption of soft X-ray quanta by cool gas before the shock front. But the effect is not large enough, so accretion shock can be responsible for the soft component of observed X-ray spectrum only. I assume that observed emission with $E > 1$ keV is produced by $T \sim 10^7$ K coronal plasmas situated within closed field lines of global stellar field near magnetic equator. Relative contribution of this region in optical and UV spectrum of CTTSs is discussed.

It was shown also that in contrast to optical radiation, intensity of accretion shock X-ray emission is practically independent on the infall gas density, i.e. the theory predicts the absence of correlation between variations in optical and X-ray bands in agreement with observations of BP Tau.

Accepted by Astronomy Letters

Preprints available through anonymous ftp: [infm1.sai.msu.ru/pub/PEOPLE/lamzin/](ftp://infm1.sai.msu.ru/pub/PEOPLE/lamzin/)

The H₂O abundance and star formation history in ρ Oph

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ISO-LWS observations towards a large number of different positions in the core of the ρ Oph cloud are used to place a limit to the abundance of wide spread H₂O. From NLTE excitation and radiative transfer modelling the average line spectrum of the ρ Oph cloud, we find $X(\text{H}_2\text{O}) < 10^{-6}$ to 10^{-5} . We interpret these results within the framework of the dynamical chemistry models by Bergin, Melnick & Neufeld (1998), which describe the time evolution of molecular clouds being shocked by outflowing gas from young stellar objects, and conclude that the ρ Oph cloud has been forming stars for less than one million years ($2-5 \times 10^5$ yr). Finally, we show that this limiting result can be put to conclusive observational test by the ODIN satellite mission in the near future.

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ftp://ftp.astro.su.se/pub/rene/rho_water.ps

Spectrum of V350 Cep: Observations in 1978-1994

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We present the results of spectral observations on the 6-m telescope in 1978-1994 of the V350 Cep, T Tau star with unusual lightcurve, located in NGC7129 star formation region. General description of the spectrum and relative intensities and radial velocities of the principal lines are given. The spectral variability of the star is described. Strong fluorescence in the FeI lines is observed. Prominent increase of intensities of the H and CaII emission lines with simultaneous blueshifting in 1982 are considered as evidence of the ejection of an additional envelope. Meanwhile, no evolutionary changes, characteristic for fuors, can be traced in the V350 Cep spectrum. This star could belong to the EX Lupi type objects (exors).

Accepted by Astrophysics

The VSOP Pre-launch H₂O Maser Survey I: VLBA Observations

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We present the first results from a H₂O Maser survey conducted with the VLBA for determining candidate sources for space VLBI missions. We observed 60 sources in total: 4 late-type stars, 29 star forming regions and 27 HII regions. These are the first interferometric observations of any kind for 50% of the sources. Approximately 30% of the sources we observed exhibit highly compact structure and very strong emission which make them ideal targets for Space-VLBI missions.

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HST/NICMOS Imaging of Disks and Envelopes Around Very Young Stars

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This is the abstract of your paper We present HST/NICMOS observations with $\sim 0''.1 \approx 15$ AU resolution of six young stellar objects in the Taurus star-formation region. The targets of our survey are three Class I IRAS sources (IRAS 04016+2610, IRAS 04248+2612, and IRAS 04302+2247) and three low-luminosity stars (DG Tau B, Haro 6-5B, and CoKu Tau/1) associated with Herbig Haro jets. The broad-band images show that the near-infrared radiation from these sources is dominated by light scattered from dusty circumstellar material distributed in a region 10 - 15 times the size of our solar system. Although the detailed morphologies of the individual objects are unique, the observed young stellar objects share common features. All of the circumstellar reflection nebulae are crossed by dark lanes from 500 - 900 AU in extent and from less than 50 to 350 AU in apparent thickness. The absorption lanes extend perpendicular to known optical and millimeter outflows in these sources. We interpret the dark lanes as optically thick circumstellar disks seen in silhouette against bright reflection nebulosity. The bipolar reflection nebulae extending perpendicular to the dust lanes appear to be produced by scattering from the upper and lower surfaces of the disks and from dusty material within or on the walls of the outflow cavities. Out of five objects in which the central source is directly detected, two are found to be subarcsecond binaries. This mini-survey is the highest resolution near-infrared study to date of circumstellar environments around solar-type stars with age ≤ 1 Myr. Accepted by Astron. J.

http://spider.ipac.caltech.edu/staff/brandner/pubs/hst_disks.ps.gz <http://xxx.lanl.gov/abs/astro-ph/9902101>

On the nature of the Herbig Be star V380 Ori

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We discuss new and archive spectroscopic and photometric observations of the Herbig Ae star V380 Ori obtained between 1978 and 1995 and covering at different epochs the wavelength range from 1200 Å to 5 μm. The coordinated JHKLM and CVF infrared observations and optical spectroscopy made at ESO of March 1985 confirm the presence of a strong IR excess due to emission from hot circumstellar dust. The comparison with IR photometry from the literature suggests the presence of oscillations, without secular variations. The optical spectrum of V380 Ori, observed at ESO during 1983–1985, and at OHP in January 1995, remained substantially stable, and was all the time characterized by a large number of broad (FWHM~150 km s⁻¹) permitted emission lines, probably formed in a **rotating optically thick disk**. The strongest Fe II lines have complex profile with a principal central emission and a blue-shifted (-140 km s⁻¹) wind component, the redward component probably being occulted by the disk. The multiplet 42 lines have P Cygni absorption components shifted by -250 km s⁻¹ which should be associated with a **tenuous cool wind**. We remark the secular behaviour of the stellar activity probe He I 5876 Å line, which is present in all our spectra as a broad emission, while in other times it was absent or in absorption. The ultraviolet (IUE) spectrum shows a short wavelength cut off at ~1300 Å typical of a B9–A0 star, with a rich absorption spectrum, which is thought to be produced in an optically thick stellar envelope or wind. The 2175 Å interstellar band strength is consistent with a mean galactic-type extinction law with an $E_{B-V} = 0.20 \pm 0.05$, much smaller than that derived from the visual (~0.5), which suggests an anomalous local UV extinction. The comparison of the archive IUE data shows that during 1978–1989 there was no significant flux variation, with the possible exception of the UV Mg II emission line.

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The preprint and Table 3 are available as ps files through: <http://www.ias.rm.cnr.it/ias-hme/preprints/prepri.htm>, or via anonymous ftp to [ftp.ias.rm.cnr/pub/uvspace/](ftp://ftp.ias.rm.cnr/pub/uvspace/)

The sulphur depletion problem

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From observations of sulphur-bearing and other molecular species and chemical models it has been established that elemental sulphur is roughly two orders of magnitude more depleted in the detectable parts of such regions than are elemental carbon, nitrogen and oxygen. It seems surprising that sulphur is so depleted but not entirely depleted. We suggest that the fact that much of the sulphur is in S⁺ in translucent clumps with hydrogen number densities of less than 10³ cm⁻³ plays a significant role in determining why it is so depleted in denser sources. Ions collide more rapidly with grains and may stick more efficiently to them than neutrals, so as a clump collapses, sulphur may become depleted in it more rapidly than elements which are not primarily ionized in translucent material. Eventually in the collapse, gas phase sulphur will become contained mostly in neutral species, which in our picture leads to a large decrease in its depletion rate and a remnant gas phase elemental fractional abundance high enough for sulphur bearing species in dense cores to be detectable.

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On the applicability of the Rayleigh approximation for coated spheroids in the near-infrared

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Calculations of the extinction and polarization profiles in the wavelength range $\lambda \lambda$ 2.7 – 22 μm have been performed

for silicate core – icy mantle spheroidal grains using the exact solution to the light scattering problem and the Rayleigh approximation.

It is concluded that the 10% accuracy of the Rayleigh approximation is guaranteed in the case of extinction (polarization) if the particle size does not exceed $r \lesssim 1.15 \mu\text{m}$ ($1.10 \mu\text{m}$), $0.85 \mu\text{m}$ ($0.35 \mu\text{m}$), $0.25 \mu\text{m}$ ($0.15 \mu\text{m}$) within the $18 \mu\text{m}$, $10 \mu\text{m}$ and $3 \mu\text{m}$ bands respectively, where r is the radius of a sphere with the same volume as a spheroid.

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The Rotation Period Distribution of Pre-Main Sequence Stars In and Around the Orion Nebula

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We report rotation periods for 254 stars in an area 40×80 arcmin centered on the Orion Nebula. We show that these stars are likely members of the young ($\sim 10^6$ yr) Orion OB1c/d association. The rotation period distribution we determine, sensitive to periods $0.1 < P < 8$ days, shows a sharp cutoff for periods $P < 0.5$ days, corresponding to breakup velocity for these stars. Above 0.5 days the distribution is consistent with a uniform distribution; we do not find evidence for a “gap” of periods at 4–5 days. We find signatures of active accretion among stars at all periods; active accretion does not occur preferentially among slow rotators in our sample. We find no correlation between rotation period and near-infrared signatures of circumstellar disks. In addition, we show that the distribution of $v \sin i$ among stars in our sample bears striking resemblance to that of low-mass Pleiads.

We discuss the implications of our findings for the evolution of stellar angular momentum during the pre-main sequence phase. We argue that all stars in our sample must still deplete angular momentum by factors ~ 5 –10 if they are to preserve their $v \sin i$ distribution over the next ~ 100 Myr. We consider in detail whether our findings are consistent with disk-regulated stellar rotation. We do not find observational evidence that magnetic disk-locking is the dominant mechanism in angular momentum evolution during the pre-main sequence phase.

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Preprints: <http://www.astro.wisc.edu/~keivan/pubs.html>

PDR Models of Photoevaporating Circumstellar Disks and Application to the Proplyds in Orion

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We have modeled the neutral flows emerging from circumstellar disks or small clumps of size r_0 illuminated by an external source of ultraviolet radiation. The models are applied to the disks (proplyds) in the Orion Nebula, most of which are illuminated by $\theta^1\text{C Ori}$. Our models improve upon the simpler models of Johnstone, Hollenbach & Bally (1998) by including the results of both equilibrium and non-equilibrium PDR codes, and by treating the flow speed off the disk surface in a more consistent manner. We present a study which delineates the parameter space (G_0 , r_0 and σ_{ext}) in which FUV-dominated, as opposed to EUV-dominated, flows exist. G_0 is the FUV ($6\text{eV} < h\nu < 13.6\text{eV}$) flux (in units of the local average interstellar flux) incident on the neutral flow at the ionization front (IF), and σ_{ext} is the dust FUV extinction cross section per H nucleus in the flow region. FUV-dominated flows are extended with sizes of the IF $r_{\text{IF}} > 2r_0$, have a shock between the disk surface and IF, and the mass loss rates are determined by FUV photons. For $\sigma_{\text{ext}} = 8 \times 10^{-22}\text{cm}^2$ and a UV source similar to $\theta^1\text{C Ori}$, the FUV-dominated region extends from $G_0 \approx 5 \times 10^4$ to $G_0 \approx 2 \times 10^7$ (or distances from $\theta^1\text{C Ori}$ of 0.3-0.01 pc) and for disk or clump size $r_0 \approx 10^{14} - 10^{15}\text{cm}$. Outside of this parameter space, hydrogen-ionizing EUV photons dominate the photoevaporation and the IF is close

to the disk surface ($r_{\text{IF}} > 2r_0$).

We show that FUV-dominated flows can explain the observed sizes of the ionization fronts around many of the photoevaporating disks in Orion. The size of the neutral flow region r_{IF} depends mainly on r_0 , G_0 and σ_{ext} inside the flow region. Using 10 objects in Orion where both r_0 and r_{IF} are directly observed, and where G_0 can be estimated from the observed projected distance of the proplyd from $\theta^1\text{C Ori}$, we find that $\sigma_{\text{ext}} \approx 8 \times 10^{-22}\text{cm}^2$ best fits the observations. In these models the disk mass loss rates are roughly $10^{-7}M_{\odot}/\text{yr}$. We have determined the disk masses for circular and radial proplyd orbits. For circular orbits around $\theta^1\text{C Ori}$ the disk masses range between $0.005\text{--}0.025 (t_i/10^5\text{yrs}) M_{\odot}$, where t_i is the illumination timescale. Comparison with millimeter observations of the disk masses ($< 0.02M_{\odot}$) indicate $t_i \approx 10^5\text{yrs}$, suggesting that $\theta^1\text{C Ori}$ is a young, $< 10^5$ year old, O star in this scenario. The timescale for the disks to significantly lose mass and shrink is $\sim 10^5\text{yrs}$. If the disks cross the Trapezium cluster on radial orbits, the proplyd masses range between $0.002\text{--}0.01 M_{\odot}$. For radial orbits the lifetime of the proplyds can be as large as the age of the Orion Cluster ($\sim 1\text{Myr}$), and $\theta^1\text{C Ori}$ can be significantly older than 10^5 years.

We have calculated the thermal and chemical structure of the flow region in the observationally best studied object 182-413 (HST-10) and the representative object 155-338. A region of atomic hydrogen extends from the IF towards the disk surface, but close to the surface hydrogen becomes molecular. The temperatures inside the atomic layer are several thousand K. We have calculated the H_2 1-0 S(1) and the H_2 2-1 S(1) vibrational line intensities, the [CII] $158\mu\text{m}$ and [OI] $63\mu\text{m}$ fine structure line intensities, and the [OI] 6300 \AA line intensity. We find good agreement between the observed H_2 1-0 S(1) line intensity (Chen et al. 1998) and the theoretically predicted one. The models can also reproduce the [OI] 6300 \AA line emission observed close to the disk surface in 182-413, 155-338 and the other proplyds where the disks can be resolved in the [OI] line. The other lines are not yet observed and we present them here as predictions for future observations.

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A molecular cloud forming in the disk–halo interface

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We present medium and high angular resolution HI and CO observations of the galactic cirrus cloud IVC 135+54–45 and compare the line emission with intensities of the IRAS $100\mu\text{m}$ and $60\mu\text{m}$ bands. Its distance above the galactic plane is about 220 pc, thus well outside the scale height of normal molecular gas (≈ 74 pc). Thus IVC 135+54–45 offers an unique possibility to study the cold interstellar medium in the transition zone between the galactic plane and the halo. We establish a linear relation between the IRAS $100\mu\text{m}$ intensities and the proton column densities in the outer part of the cloud where the H_2 content is negligible. In the centre of the cloud we find two clumps which have more FIR-emission than can be accounted for by a linear $N(\text{HI})/I_{100}$ correlation. The clumps are connected to HI filaments. A detailed analysis of one of the clumps reveals that the FIR-excess is associated mainly with the filament and to a lesser degree with the clump. This result is in contradiction to our CO observations which show strong emission in the clump and only weak emission in the filament. We have evidence that the FIR-excess in the filament is partly caused by an increased dust temperature and not due to the existence of H_2 alone. We conclude that the filament and the clump represent different epochs in the transition from atomic to molecular gas. The clump is more evolved and might be close to chemical equilibrium while formation of molecular gas has not reached equilibrium in the filament. We ascribe the increased temperature in the filament to chemical energy released by H_2 formation on dust grains.

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<http://www.astro.uni-bonn.de/~aweiss/paper7923.ps.gz>

A Test of Pre-Main Sequence Evolutionary Models Across the Stellar/Substellar Boundary Based on Spectra of the Young Quadruple GG Tau

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We present spatially separated optical spectra of the components of the young hierarchical quadruple GG Tau. Spectra of GG Tau Aa and Ab (separation $0''.25 \sim 35$ AU) were obtained with the Faint Object Spectrograph aboard the Hubble Space Telescope. Spectra of GG Tau Ba and Bb (separation $1''.48 \sim 207$ AU) were obtained with both the HIRES and the LRIS spectrographs on the W. M. Keck telescopes. The components of this mini-cluster, which span a wide range in spectral type (K7 - M7), are used to test both evolutionary models and the temperature scale for very young, low mass stars under the assumption of coeval formation. Of the evolutionary models tested, those of Baraffe et al. (1998) yield the most consistent ages when combined with a temperature scale intermediate between that of dwarfs and giants. The version of the Baraffe et al. models computed with a mixing length nearly twice the pressure scale height is of particular interest as it predicts masses for GG Tau Aa and Ab that are in agreement with their dynamical mass estimate.

Using this evolutionary model and a coeval (at 1.5 Myrs) temperature scale, we find that the coldest component of the GG Tau system, GG Tau Bb, is substellar with a mass of $0.044 \pm 0.006 M_{\odot}$. This brown dwarf companion is especially intriguing as it shows signatures of accretion, although this accretion is not likely to alter its mass significantly. 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.

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Preprints available through <http://xxx.lanl.gov/abs/astro-ph/9902318>

Extended mid-infrared emission around the outflow source and the compact H II region in AFGL 4029

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We present the first sub-arcsecond $8 - 13 \mu\text{m}$ images of the young stellar cluster AFGL 4029, obtained using the camera CAMIRAS mounted at the Canada-France-Hawaii Telescope.

The two dominant components of the cluster, a highly obscured young stellar object (YSO) and a compact H II region excited by a B1 star, are both spatially resolved and show the $11.3 \mu\text{m}$ band in emission. The dust composition and excitation in the AFGL 4029 H II region appear similar to those in other compact H II regions of moderate excitation observed by ISO-SWS. In addition, we observe that the $11.3 \mu\text{m}$ feature/continuum ratio decreases toward the main exciting star on scales ≤ 8800 AU. The large extent of the mid-infrared emission from the YSO is so far a unique example among deeply embedded objects. It suggests that there is no simple trend relating the mid-IR size and the evolutionary status in young stars. The emission arises in optically thin circumstellar dust, possibly in a cavity carved by the bipolar outflow.

An optical and near-infrared reflection nebulosity present $5''$ away from the YSO is also detected in the mid infrared. It is particularly bright in the $11.3 \mu\text{m}$ feature, with a feature/continuum ratio ~ 4 comparable to that seen in prototypical reflection nebulae. Finally, mid-IR emission associated with an optical jet knot in the same zone suggests that shocks, by creating small particles, might explain the high surface brightness in this region.

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Dissertation Abstracts

Radiation hydrodynamical simulations of photoevaporating disks around young stars and protostars

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Ph.D degree awarded: December 1998

Circumstellar disks are a phenomenon frequently observed during the formation process of stars and planets. Young massive stars produce hydrogen-ionizing photons (EUV photons with energies $h\nu \geq 13.6$ eV) and are able to photoevaporate their own disks and the disks of low-mass objects in their immediate environment. Radiation hydrodynamical simulations are used to examine the interaction of circumstellar disks with the EUV photons and the stellar wind of the central star as well as the interaction of circumstellar disks with the EUV photons of an external source.

An improved radiation hydrodynamics code solves the hydrodynamical equations including turbulent viscosity and self-gravity for a mixture of gas and dust. A continuum radiation transfer subroutine determines the dust temperature and the radiative acceleration. The transfer of EUV photons is calculated along radial lines of sight. This part of the code includes an implicit solution algorithm for the energy equation which solves the time-dependent rate equation for the degree of ionization of hydrogen and considers heating and cooling mechanisms most important for EUV-dominated regions. In addition, the transfer of diffuse EUV radiation is calculated for photons resulting from the recombination of hydrogen into the ground state and from scattering on dust grains. The calculations start with star-disk systems resulting from collapse simulations.

The EUV photons of the central object of a star-disk system continuously photoevaporate the disk which leads to the formation of an ultracompact HII (UCHII) region. The lifetime of the UCHII region is determined by the photoevaporation rate of the disk. The simulations show that the diffuse EUV radiation field resulting from scattering on dust grains is important for the evolution of photoevaporating disks. Depending on the absorption and scattering properties of the dust particles the photoevaporation rate varies an order of magnitude. In addition, the code was used to examine systematically the dependence of the photoevaporation rate on the parameters of the ionizing star. The dependence of the photoevaporation rate \dot{M}_{ph} on the stellar EUV photon rate S is consistent with semi-analytical calculations ($\dot{M}_{\text{ph}} \propto S^{0.58}$). The influence of the velocity and mass loss rate of the stellar wind is strongly dependent on the modeling of the wind and the structure of the disk. Hydrodynamical collimated bipolar outflows are created without invoking magnetic fields.

The interaction of circumstellar disks with the EUV photons of an external star is calculated for a $0.58 M_{\odot}$ star surrounded by a $0.40 M_{\odot}$ disk. The external EUV flux is chosen to match the situation of the objects close to the Trapezium star θ^1 Ori C in the Orion Nebula called proplyds. Cometary tails develop and break off into filaments which leave the immediate vicinity of the disk with the evaporating flow. The total mass of the disk fragments which break off during the relatively short cometary phase is of order 10% of the disk mass. After several 10^4 yr the disk is completely enveloped by the ionization front. With decreasing distance the densest parts of the disk remnant are more strongly disturbed. Applying a diagnostic ray-tracing procedure to the resulting structures shows that the disks in the cometary phase reproduce the typical head-tail structure of the proplyds.

However, observations reveal a stand-off of the ionization front from the disk at several disk radii. This property of the proplyds can be explained by a non-negligible flux of FUV photons ($6 \text{ eV} \leq h\nu \leq 13.6 \text{ eV}$). A FUV module was developed which calculates the transfer of direct FUV photons, the transfer of diffuse FUV photons resulting from scattering on dust grains, the ionization of carbon and additional heating and cooling functions. Simulations including the FUV module show that FUV photons heat the region between the disk surface and the ionization front to temperatures up to 1500 K and generate a wind of neutral material which prevents the ionization front from reaching the disk surface. Part of the neutral wind is redirected to the side of the disk opposed to the ionizing star. The redirection rate is $\sim 20\%$ of the photoevaporation rate. Due to this process the region behind the disk is continuously filled up with neutral material causing long-living tails ($\sim 10^6$ yr). Simulations with warmer (~ 5000 K) neutral disk winds, with more powerful stellar winds and different star-disk models would help to retrieve further information on the nature of proplyds.

Meetings

Imaging at Radio through Submillimeter Wavelengths

6-9 June, 1999

Loews Ventana Canyon Resort

Tucson, AZ

<http://www.tuc.nrao.edu/imaging99>

Imaging at Radio through Submillimeter Wavelengths will bring together scientists and engineers working in the rapidly developing field of astronomical imaging at radio through submillimeter wavelengths.

Topics include:

- Single dish heterodyne imaging
- Bolometric imaging
- Techniques for acquiring and processing single dish images
- Interferometric multi-field imaging
- Phase and amplitude calibration techniques for interferometric imaging
- Algorithms for processing interferometric multi-field images

Preliminary list of invited speakers:

P. Andre, L. Bronfman, R. Brown, T. Cornwell, D. Emerson, R. Fisher, R. Güsten, D. Hartmann, T. Hasegawa, M. Heyer, L. Higgs, P. Ho, W. Holland, R. Kawabe, C. Kramer, C. Lada, N. Neininger, R. Plambeck, J. Richer, R. Sault, L. Staveley-Smith, J. Stutzki, L. Testi, J. Welch, and J. Wiseman.

Organizers:

The conference will be organized and hosted by the National Radio Astronomy Observatory. The Organizing Committee is composed of Philippe Andre, Darrel Emerson, Mark Gordon, David Hogg, Phil Jewell, Harvey Liszt, Jeff Mangum (chair), Simon Radford, Goeran Sandell, and Al Wootten.

Imaging at Radio through Submillimeter Wavelengths is currently limited to approximately 150 participants. The proceedings from this conference will be published in the Astronomical Society of the Pacific (ASP) Conference Series. For further information regarding registration and accomodations, see *<http://www.tuc.nrao.edu/imaging99>*.

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