THE HOT STAR NEWSLETTER

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An electronic publication dedicated to A, B, O, Of, LBV and Wolf-Rayet stars
and related phenomena in galaxies

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Accepted Papers

Stellar evolution with rotation X: Wolf-Rayet star populations at solar metallicity

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We examine the properties of Wolf–Rayet (WR) stars predicted by models of rotating stars taking account of the new mass loss rates for O–type stars and WR stars (Vink et al.; Nugis & Lamers) and of the wind anisotropies induced by rotation. We find that the rotation velocities v of WR stars are modest, i.e. about 50 km s^{-1}, not very dependant on the initial v and masses. For the most massive stars, the evolution of v is very strongly influenced by the values of the mass loss rates; below ∼12 M$_\odot$ the evolution of rotation during the MS phase and later phases is dominated by the internal coupling. Massive stars with extreme rotation may skip the LBV phase.

Models having a typical v for the O–type stars have WR lifetimes on the average two times longer than for non–rotating models. The increase of the WR lifetimes is mainly due to that of the H–rich eWNL phase. Rotation allows a transition WN/WC phase to be present for initial masses lower than 60 M$_\odot$. The durations of the other WR subphases are less affected by rotation. The mass threshold for forming WR stars is lowered from 37 to 22 M$_\odot$ for typical rotation. The comparisons of the predicted number ratios WR/O, WN/WC and of the number of transition WN/WC stars show very good agreement with models with rotation, while this is not the case for models with the present–day mass loss rates and no rotation. As to the chemical abundances in WR stars, rotation brings only

very small changes for WN stars, since they have equilibrium CNO values. However, WC stars with rotation have on average lower C/He and O/He ratios. The luminosity distribution of WC stars is also influenced by rotation.

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or on the web at http://arXiv.org/abs/astro-ph/0304069

Magnetic Rotator Winds and Keplerian Disks of Hot Stars

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We set up equations and boundary conditions for magnetic rotator winds and disks in axially symmetric hot stars in a steady state. We establish a theorem stating that if a disk region has no meridional motion but its magnetic field has a normal component at a point Q on its shock boundary, the angular velocity of the disk region at Q is the same as the angular velocity of the star at the point $P_\star$ at which the magnetic field line through Q is anchored. When there is equatorial symmetry, all points of the disk along the field line through Q will have the same angular velocity as $P_\star$. Also, we show that for a given value of the magnetic field strength, if the rotation rate is too high or the flow velocity into the shock boundary is too low, a Keplerian disk region will not be formed. We consider the formation of disks in magnetic rotators through the processes of fill-up and diffusion into Keplerian orbits. At the end of the fill-up stage the density of the disk increases significantly and the magnetic force in the disk becomes negligible. If the meridional component B_m of the field at the surface is larger than a minimum value $B_{m,min}$, a Keplerian disk can form. The radial extent of the Keplerian region is larger for larger values of B_m and is largest when B_m equals an optimal value $B_{m,opt}$. The extent does not increase when B_m is larger than $B_{m,opt}$. If α is the ratio of rotational speed to the critical rotation speed at the photosphere, the inner and outer radii of the maximal quasi-steady Keplerian disk region are given by $\alpha^{-2/3}R$ and $2^{4/3}\alpha^{-2/3}R$, respectively, where R is the stellar radius. For models with dipole-type fields, the values of $B_{m,min}$ in B-type stars are of order 1 G to 10 G and in O-type stars they are about 500 G. Because the values of B_m required for disk formation in B-type stars are relatively small and the fill-up time is short, we suggest that meridional circulation may play a role in some of the time-variation observed in disks of Be stars through its effect on the magnetic field near the photosphere.

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Preprints from mmaheswa@uwc.edu

Ionization structure in the winds of B[e] supergiants I. Ionization equilibrium calculations in a H plus He wind

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The non-spherically symmetric winds of B[e] supergiants are investigated. An empirical density distribution is chosen that accounts for the density concentrations and ratios derived from observations, and our model winds are assumed to contain only hydrogen and helium. We first calculate the approximate

ionization radii for H and He and compare the results with the ionization fractions calculated from the more accurate ionization balance equations. We find that winds with a r^{-2} density distribution turn out to reach a constant ionization fraction as long as the wind density is low, i.e. in polar direction. For the high density equatorial regions, however, we find that the winds become neutral just above the stellar surface of the hot and massive B[e] supergiants forming a disk-like neutral region. In such a disk molecules and dust can form even very near the hot central star.

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The Massive Binary CPD $-$ 41° 7742: I. High-Resolution Optical Spectroscopy.

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We present the results of a spectroscopic campaign on the early-type binary CPD $-$ 41° 7742. For the first time, we unambiguously detect the secondary's spectral signature and derive an accurate orbital solution for both components of the system. We confirm that the orbit displays a slight but definite eccentricity ($e = 0.027 \pm 0.006$) despite the short period ($P = 2.44070 \pm 0.00043$ days). Previous radial velocity measurements available in the literature constitute together with our new observations a data set that spans more than 30 years. The combined primary orbital solution inferred is in excellent agreement with our solution and gives a period $P = 2.44062 \pm 0.00005$ days. Based on spectroscopic criteria, we derive a spectral and luminosity classification of O9 III + B1 III. However, the luminosities and radii inferred from the membership of NGC 6231 rather indicate lower luminosity classes. We show that the equivalent widths of well isolated primary lines display variations that suggest that CPD $-$ 41° 7742 is an eclipsing binary. This makes CPD $-$ 41° 7742 the second known SB2 eclipsing early-type binary of the NGC 6231 cluster. We approximately constrain the inclination of the system $i_{\rm min} \approx 60°$. This may indicate that the system does not offer enough room for two stars with radii typical of giant stars and lends further support to a less evolved luminosity classification for at least one of the objects.

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Surface modelling of nonradial pulsators: alternative formalisms within the linear approximation

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The problem of modelling the surface of stars undergoing nonradial pulsation is reviewed. Linear-approximation expressions for the surface radius, temperature, velocity and geometry of a pulsating star are derived and discussed using both the Lagrangian (fixed-element) and Eulerian (fixed-position)

formalisms. In each case, small numerical discrepancies are found between the perturbed states predicted by these alternative approaches. These discrepancies are shown to scale quadratically with the pulsation amplitude, and are therefore attributed to a transgression of the linear-approximation limits.

Singled out for particular attention are the expressions for the surface geometry perturbations predicted by each formalism. Marked differences are apparent between these expressions: terms containing the horizontal fluid displacement appear explicitly in the Lagrangian result, but are absent from the corresponding Eulerian one. By examining the physical origin of these terms, it is demonstrated that the two formalisms are, in fact, perfectly consistent with regard to the geometry perturbations, and – as with all other perturbations – simply furnish alternative representations of the same physical processes. The conclusion is that either formalism is an appropriate choice when modelling the surface of a pulsating star.

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or on the web at http://www.star.ucl.ac.uk/~rhdt/publications/

High resolution spectroscopy of HD 207538 from Far-UV (FUSE) to Visible (SARG-TNG) A global picture of the stellar and interstellar features modeled.

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We present a detailed study of the suspected Chemically Peculiar star HD 207538 based on high resolution spectroscopy in the far Ultraviolet (1000-3350 Å) and visible (4600-7000 Å) ranges. The stellar abundance synthesis analysis was performed by using Kurucz's codes ATLAS9 and SYNTHE to compute the atmospheric model and the synthetic spectrum respectively.
Observations were obtained with the *Far Ultraviolet Spectroscopic Explorer*, the *International Ultraviolet Explorer* satellites whereas the optical spectrum was collected with the ground-based *Telescopio Nazionale Galileo* telescope.
With our analysis we refine the value of the rotational velocity to $v_e \sin i = 42 \pm 3$ km s^{-1} and the microturbulence velocity to $\xi = 8 \pm 1$ km s^{-1}. The stellar abundances inferred in this study show that C, N, O, Al, Si, P, S and Mn are compatible with the standard solar abundances, within the experimental errors. On the other hand, Fe, Ni and Zn are definitively underabundant. We also show that the helium content is comparable to the typical abundance of B-type stars.
Because this spectrum is rich in stellar and interstellar features, we computed simultaneously a synthetic spectrum of the stellar and interstellar lines in order to disentangle the different absorption contributions. We thus also determined the column densities of several interstellar elements (FeII, NI, PII, HI, H_2, HD, CO, ClI and ArI) present in the gas in front of the star. Although several components are present along this sightline, our results suggest the presence of some translucent interstellar gas among the diffuse components.
With this work, we demonstrate that it is possible to perform a stellar spectroscopic analysis from

the far-UV to visible spectral range, with consistent results in both ranges within errors, based on one single atmosphere model.

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or on the web at http://webusers.ct.astro.it/gca/referred.htm

The impact of radiation and wind momenta on mass transfer in massive close binary systems

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We investigate to what extent the radiation and stellar wind momenta in a massive close binary system can remove part of the matter flowing from one towards the other star during a mass transfer phase. We perform radiation-hydrodynamics simulations in the co-rotating frame of a binary system made-up of two main sequence stars of $27\,M_\odot$ and $26\,M_\odot$ in a 4 day orbit. We study the interaction of the winds of both stars, and of their photons, with the accretion stream originating from the Roche-lobe filling component. For our simulation, we adopt a mass transfer rate of $5 \times 10^{-6} M_\odot\, yr^{-1}$, a mid-point in the range of values during massive binary star evolution. Our simulations show that even for such moderate mass transfer rates, the wind and radiative momenta do not alter the dynamics of the accretion stream which is observed to follow essentially ballistic trajectories. Such a conclusion is reinforced for higher mass transfer rates because of the increased stream density and the correspondingly reduced radiation force. We anticipate that the radiation and wind momenta will affect the accretion stream only when its density is comparable to the wind's, a situation wherein the mass transfer rate is vanishingly small and irrelevant for binary star evolution. Alternatively, such reduced accretion stream density could be obtained from spatial dilution in wider systems, potentially leading to non-conservative mass transfer.

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η Carinae: the optical flare-like events during low-excitation events

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The 1992.5 and 1998.0 low-excitation events of the possible binary in the core of η Carinae show a conspicuous flare-like event in optical and near-ultraviolet light. These events last a couple of months and have a light amplitude of $0\overset{\mathrm{m}}{.}1$–$0\overset{\mathrm{m}}{.}2$ in V. Considering the presence of a dense (bi-polar) stellar wind, one explanation could be that some type of a hot area is created by an increased mass flow from the S Dor primary near the hypothetical periastron. These flare-like events are terminated by sharp dips. The magnitude differences between the underlying light source and the central light ('Component A') are derived. It turns out that they are fainter than Component A by $\sim 2\overset{\mathrm{m}}{.}5$. The luminosity could be of the order of $10^5\, L_\odot$. It was possible to derive two new continuum values in the

near-UV, reinforcing the impression derived from the HST fluxes that Component A has a very strong radiation peak in the Balmer continuum. This can probably be explained by the strong emission of the stellar wind.

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Two Molecular Clouds near M 17

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We present fully sampled images in the $C^{18}O$ $J = 2 - 1$ line extending over 13′ by 23′, made with the Heinrich-Hertz-Telescope (HHT) on Mt. Graham. The HHT has a resolution of 35″ at the line frequency. This region includes two molecular clouds. Cloud A, to the north, is more compact, while Cloud B, is to the west of the H II region M 17. Cloud B contains the well known source M 17SW. In $C^{18}O$ we find 13 maxima in Cloud A, and 39 in Cloud B. Sixteen sources in Cloud B are in M 17SW, mapped previously with higher resolution. In cloud B, sources outside M 17SW have linewidths comparable to those in M 17SW. In comparison, Cloud A has lower $C^{18}O$ line intensities and smaller linewidths but comparable densities and sizes. Maps of the cores of these clouds were also obtained in the $J = 5 - 4$ line of CS, which traces higher H_2 densities. Our images of the cores of Cloud A and B show that for $V_{LSR} \leq 20$ km s^{-1}, the peaks of the CS emission are shifted closer to the H II region than the $C^{18}O$ maxima, so higher densities are found toward the H II region. Our CS data give additional support to the already strong evidence that M 17SW and nearby regions are heated and compressed by the H II region. Our data show that Cloud A has a smaller interaction with the H II region. We surmise that M 17SW was an initially denser region, and the turn-on of the H II region will make this the next region of massive star formation. Outside of M 17SW, the only other obvious star formation region may be in Cloud A, since there is an intense mm dust continuum peak found by Henning et al. (1998), but no corresponding $C^{18}O$ maximum. If the CO/H_2 ratio is constant, the dust must have a temperature of ∼100K or the H_2 density is $>10^6$cm^{-3} or both to reconcile the $C^{18}O$ and dust data. Alternatively, if the CO/H_2 ratio is low, perhaps much of the CO is depleted.

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Two-Dimensional Simulations of the Line-Driven Instability in Hot-Star Winds

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We report initial results of two-dimensional simulations of the nonlinear evolution of the line-driven instability (LDI) in hot-star winds. The method is based on the Smooth Source Function (SSF) formalism for nonlocal evaluation of the radial line-force, implemented separately within each of a set of radiatively isolated azimuthal grid zones. The results show that radially compressed "shells" that develop initially from the LDI are systematically broken up by Rayleigh-Taylor or thin-shell instabilities as these structures are accelerated outward. Through radial feedback of backscattered radiation, this leads ultimately to a flow structure characterized by nearly complete lateral incoherence, with structure extending down to the lateral grid scale, which here corresponds to angle sizes of order a fifth of a degree. We briefly discuss the implications for interpreting various observational diagnostics of wind structure, but also emphasize the importance of future extensions to include lateral line-drag effects of diffuse radiation, which may set a minimum lateral scale for break-up of flow structure.

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New type of brightness variations of the WO4+O5((ff)) colliding wind binary WR 30a

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We present new photometric observations in Johnson V and B of the WO4+O5((ff)) colliding wind binary WR 30a, revealing relatively dramatic brightness changes of 0.2 mag. These variations occur on a time scale of hours, and are only seen in V. We argue that they are not caused by dust extinction, but either by a dramatic change in the strength of the C IV 5801-12 Å emission line doublet due to a de-excitation process, or by some unknown continuum effect.

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Preprint on the web at ftp://ftp.sron.nl/pub/karelh/UPLOADS/papers.dir/WR30a.ps

Radio emission models of Colliding-Wind Binary Systems

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We present calculations of the spatial and spectral distribution of the radio emission from a wide WR+OB colliding-wind binary system based on high-resolution hydrodynamical simulations and solutions to the radiative transfer equation. We account for both thermal and synchrotron radio emission, free-free absorption in both the unshocked stellar wind envelopes and the shocked gas, synchrotron self-absorption, and the Razin effect. To calculate the synchrotron emission several simplifying assumptions are adopted: the relativistic particle energy density is a simple fraction of the thermal particle energy density, in equipartition with the magnetic energy density, and a power-law in energy. We also assume that the magnetic field is tangled such that the resulting emission is isotropic. The applicability of these calculations to modelling radio images and spectra of colliding-wind systems is demonstrated with models of the radio emission from the wide WR+OB binary WR 147. Its synchrotron spectrum follows a power-law between 5 and 15 GHz but turns down to below this at lower and higher frequencies. Free-free opacity from the circum-binary stellar winds alone cannot account for the low-frequency turnover, but must be augmented by a combination of synchrotron self-absorption and Razin effect. We argue that the high-frequency turn down is a consequence of inverse-Compton cooling. We present our resulting spectra and intensity distributions, along with simulated MERLIN observations of these intensity distributions. From these we argue that the inclination of the WR 147 system to the plane of the sky is low. We summarise by considering extensions of the current model that are important for models of the emission from closer colliding wind binaries, in particular the dramatically varying radio emission of WR 140.

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Preprints from `sean.dougherty@nrc.ca`
or by anonymous ftp to `ftp://ftp.drao.nrc.ca/pub/smd/theory_paper/theory_paper.pdf`
or on the web at `http://www.drao.nrc.ca/ smd/preprint/theory_paper.pdf`

Submitted Papers

Stellar and wind parameters of Galactic O-stars. The influence of line-blocking/blanketing

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Abstract: We have re-analyzed the Galactic O-star sample from Puls et al. (1996) by means of line-blanketed NLTE model atmospheres in order to investigate the influence of line-blocking/blanketing on the derived parameters. The analysis has been carried out by fitting the photospheric and wind lines from H and He. In most cases we obtained a good fit quality, but we have also found certain inconsistencies which are probably related to a still inadequate treatment of the wind structure. These inconsistencies comprise the line cores of Hgamma and Hbeta in supergiants (the synthetic profiles are too weak when the mass-loss rate is determined by matching Halpha) and the "generalized dilution effect" (cf. Voels et al. 1989) which is still present in HeI 4471 of cooler supergiants and giants.

Compared to pure H/He plane-parallel models we found a decrease in effective temperatures which is largest at earliest spectral types and for supergiants (with a maximum shift of roughly 8,000 K). This finding is explained by the fact that line-blanketed models of hot stars have photospheric He ionization fractions similar to those from unblanketed models at higher Teff and higher log g. Consequently, any line-blanketed analysis based on the He ionization equilibrium results in lower Teff-values along with a reduction of either log g or helium abundance (if the reduction of log g is prohibited by the Balmer line wings). Stellar radii and mass-loss rates, on the other hand, remain more or less unaffected by line-blanketing.

We have calculated “new” stellar masses and compared them with previous results. Although the former mass discrepancy (Herrero et al. 1992) becomes significantly reduced a systematic trend for masses below 50 Msun seems to remain: The spectroscopically derived values are smaller than the “evolutionary masses” by roughly 10 Msun. Additionally, a significant fraction of our sample stars stays over-abundant in He, although the actual values were found to be lower than previously determined.

Also the wind-momentum luminosity relation (WLR) changes because of lower luminosities and almost unmodified wind-momentum rates. Compared to previous results, the separation of the WLR as a function of luminosity class is still present but now the WLR for giants/dwarfs is consistent with theoretical predictions. On various evidence we argue that the different WLRs can be “unified” by assuming that the derived mass-loss rates of stars with Halpha in emission are affected by clumping in the lower wind region, with a typical clumping factor of 5.

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Preprints from repo@usm.uni-muenchen.de
or on the web at http://www.usm.uni-muenchen.de/people/adi/Group/hotstar.html

The Massive Triple Star System HD 16429 A

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HD 16429 A is a triple star system consisting of a single-lined spectroscopic binary and a widely separated third component, previously identified via speckle interferometry. Here I present the first orbital elements for the unblended spectroscopic binary as well as estimates of the spectral types and relative flux contributions for each visible component based upon a Doppler tomographic reconstruction of their spectra. There are several stars around HD 16429 A, including the nearby Be X-ray binary and microquasar LS I +61°303, which all probably belong to a sub-cluster within the Cas OB6 association.

Submitted to ApJ
Preprints from mcswain@chara.gsu.edu

Meetings

SIRTF Observation Planning Workshop
Pasadena, USA – 25/26 July 2003

The SIRTF Science Center (SSC) is pleased to announce a 2-day observation planning workshop to be held at the SSC, Pasadena, CA, on 25-26 July 2003. The format of this workshop will be similar to the ones held at the SSC in November and December 2002 and will provide insight and information on SIRTF capabilities, plus the observation and proposal planning tools available for download from the SSC website.

There is no registration fee associated with the workshop, but we only have 40 workshop places available. Ph.D.-level astronomers and graduate students are eligible to attend. No restrictions are made as to nationality or institution. Places at the workshop will be given on a first-come-first-served basis.

If you are interested in attending, workshop information, registration and hotel information is available online at

http://sirtf.caltech.edu/SSC/ost/workshop/2003b/

The deadline for the hotel block booking is 11 July.

We look forward to seeing you this summer at the SSC.

Cheers
SSC Observer Support Team.