THE MASSIVE STAR NEWSLETTER

formely known as *the hot star newsletter*

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Contents of this newsletter

From the Editor

As announced, several changes have been made to this newsletter and the related web site.

The newsletter used to miss many papers of interest. To help improve this situation, since November 2003 I have been scanning the `astro-ph` preprint database in search for relevant abstracts of accepted papers. I am also sending the call for abstract to more addresses.

Many readers prefer to download a reader-ready version than compile a latex file. The latex file is still available but now the newsletter is also accessible as a `pdf` file from our web site.

The web site at Guanajuato was notoriously slow. The newsletter web pages have been moved to a much faster site. At the same time, several improvements in content and in look have been made to the web pages. Many thanks to Gloria Koenigsberger for gaining us access to UNAM computers!

`http://www.astroscu.unam.mx/massive_stars/`

Finally, the newsletter is now distributed under a new name, to emphasize the universal importance of *massive* stars in all parts of the upper HRD.

Accepted Papers

The Effective Temperatures of Hot Stars II. The Early-O Types.

Miriam Garcia[1,2] and Luciana Bianchi[1]

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We derived the stellar parameters of a sample of Galactic early-O type stars by analysing their UV and Far-UV spectra from *FUSE* (905-1187Å), *IUE*, *HST-STIS* and *ORFEUS* (1200-2000Å). The data have been modeled with spherical, hydrodynamic, line-blanketed, non-LTE synthetic spectra computed with the *WM-basic* code. We obtain effective temperatures ranging from $T_{\rm eff}$= 41,000 K to 39,000 K for the O3-O4 dwarf stars, and $T_{\rm eff}$= 37,500 K for the only supergiant of the sample (O4 If$^+$). Our values are lower than those from previous empirical calibrations for early-O types by up to 20%. The derived luminosities of the dwarf stars are also lower by 6 to 12%; however, the luminosity of the supergiant is in agreement with previous calibrations within the error bars. Our results extend the trend found for later-O types in a previous work by Bianchi & Garcia.

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Preprints from garcia@pha.jhu.edu
or by anonymous ftp to
or on the web at http://arXiv.org/abs/astro-ph/0402207

Early-type stars in the young open cluster IC 1805 I. The SB2 system BD+60° 497 and the probably single stars BD+60° 501 and BD+60° 513

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We investigate the multiplicity of three O-type stars in the very young open cluster IC 1805. All our targets were previously considered as spectroscopic binaries, but no orbital solution was available for any of them. Our results confirm the binarity of BD+60° 497 and we provide the very first orbital solution for this double-lined spectroscopic binary. This is only the second O-star binary in IC 1805, and the first SB2 system, for which an orbital solution is now available. BD+60° 497 has an orbital period of 3.96 days and consists of an evolved O6.5 V((f)) primary and an O8.5-9.5 V((f)) secondary with minimum masses of $m_1 \sin^3 i = 13.9\,{\rm M}_\odot$ and $m_2 \sin^3 i = 10.9\,{\rm M}_\odot$. The observed primary/secondary mass ratio (1.28) appears lower than expected from a comparison with single star evolutionary models (1.60 – 1.74). For the other two stars, BD+60° 501 and BD+60° 513, we find no significant radial velocity variations, suggesting that they are most probably single. Although a fraction of binaries among the early-type stars of IC 1805 as high as 80% has been advocated in the literature, our results suggest that this number might be overestimated.

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Preprints from rauw@astro.ulg.ac.be
or on the web at http://vela.astro.ulg.ac.be/Preprints/P91/index.html

WR 20a: a massive cornerstone binary system comprising two extreme early-type stars

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TEXT OF ABSTRACT below this line We analyse spectroscopic observations of WR 20a revealing that this star is a massive early-type binary system with a most probable orbital period of ~ 3.675 days. Our spectra indicate that both components are most likely of WN6ha or O3If*/WN6ha spectral type. The orbital solution for a period of 3.675 days yields extremely large minimum masses of 70.7 ± 4.0 and $68.8 \pm 3.8\,M_\odot$ for the two stars. These properties make WR 20a a cornerstone system for the study of massive star evolution.

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Modeling the near-infrared lines of O-type stars

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We use a grid of 30 line-blanketed unified stellar photosphere and wind models for O-type stars; computed with the code CMFGEN in order to evaluate its potential in the near-infrared spectral domain. The grid includes dwarfs, giants and supergiants. We analyse the equivalent width behaviour of the 20 strongest lines of hydrogen and helium in spectral windows that can be observed using ground-based instrumentation and compare the results with observations. Our main findings are that: *i)* He I/ He II line ratios in the J, H and K bands correlate well with the optical ratio employed in spectral classification, and can therefore be used to determine the spectral type; *ii)* in supergiant stars the transition from the stellar photosphere to the wind follows a shallower density gradient than the standard approach followed in our models, which can be mimicked by adopting a lower gravity in our prescription of the density stratification. *iii)* the Brγ line poses a number of peculiar problems which might be partly related to wind clumping, and *iv)* the Brα line is an excellent mass-loss indicator. For the first and last item we provide quantitative calibrations.

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For preprints, contact lenorzer@science.uva.nl
*or on the web at*http://fr.arxiv.org/abs/astro-ph/0404351

A Steady, Radiative-Shock Method for Computing X-Ray Emission from Colliding Stellar Windsin Close, Massive-Star Binaries

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We present a practical, efficient, semi-analytic formalism for computing steady-state X-ray emission from radiative shocks between colliding stellar winds in relatively close (orbital period up to order tens of days), massive-star, binary systems. Our simplified approach idealizes the individual wind flows as smooth and steady, ignoring the intrinsic instabilities and associated structure thought to occur in such flows. By also suppressing thin-shell instabilities for wind-collision radiative shocks, our steady-state approach avoids the extensive structure and mixing that has thus far precluded reliable computation of X-ray emission spectra from time-dependent hydrodynamical simulations of close-binary, wind-collision systems; but in ignoring the unknown physical level of such mixing, the luminosity and hardness of X-ray spectra derived here represent upper limits to what is possible for a given set of wind and binary parameters. A key feature of our approach is the separation of calculations for the small-scale shock-emission from the ram-pressure-balance model for determing the large-scale, geometric form of the wind-wind interaction front. Integrating the localized shock emission over the full interaction surface, and using a warm-absorber opacity to take account of attenuation by both the smooth wind and the compressed, cooled material in the interaction front, the method can predict spectra for a distant observer at any arbitrary orbital inclination and phase. We illustrate results for a sample selection of wind, stellar, and binary parameters, providing both full X-ray light curves as well as detailed spectra at selected orbital phases. The derived spectra typically have a broad characteristic form, and by synthetic processing with the standard XSPEC package, we demonstrate that they simply cannot be satisfactorily fit with the usual attentuated single- or two-temperature thermal-emission models. We conclude with a summary of the advantages and limitations of our approach, and outline its potential application for interpreting detailed X-ray observations from close, massive-star binary systems.

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Preprints from owocki@bartol.udel.edu
or on the web at http://www.bartol.udel.edu/∼owocki/preprints/colwindxrays.pdf

Quantitative studies of the Far-UV, UV and optical spectra of late O and early B-type supergiants in the Magellanic Clouds

C. J. Evans, P. A. Crowther, A. W. Fullerton, D. J. Hillier

We present quantitative studies of 8 late O and early B-type supergiants in the Magellanic Clouds using far-ultraviolet FUSE, ultraviolet IUE/HST and optical VLT-UVES spectroscopy. Temperatures, mass-loss rates and CNO abundances are obtained using the non-LTE, spherical, line-blanketed model atmosphere code of Hillier & Miller (1998). We support recent results for lower temperatures of OB-type supergiants as a result of stellar winds and blanketing, which amounts to 2000 K at B0 Ia. In general, Hα derived mass-loss rates are consistent with UV and far-UV spectroscopy, although from consideration of the SIV $\lambda\lambda$1063-1073 doublet, clumped winds are preferred over homogenous models. AV 235 (B0 Iaw) is a notable exception, which has an unusually strong Hα profile that is inconsistent with the other Balmer lines and UV wind diagnostics. We also derive CNO abundances for our sample, revealing substantial nitrogen enrichment, with carbon and oxygen depletion. Our results are supported by comparison with the Galactic supergiant HD 2905 (BC0.7 Ia) for which near-solar CNO abundances are obtained. This bolsters previous suggestions that "normal" OB-type supergiants exhibit atmospheric compositions indicative of partical CNO processing.

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Infrared Observations of the Candidate LBV 1806-20 & Nearby Cluster Stars

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We report near-infrared photometry, spectroscopy, and speckle imaging of the hot, luminous star we identify as candidate LBV 1806-20. We also present photometry and spectroscopy of 3 nearby stars, which are members of the same star cluster containing LBV 1806-20 and SGR 1806-20. The spectroscopy and photometry show that LBV 1806-20 is similar in many respects to the luminous "Pistol Star", albeit with some important differences. They also provide estimates of the effective temperature and reddening of LBV 1806-20, and confirm distance estimates, leading to a best estimate for the luminosity of this star of $> 5 \times 10^6 L_\odot$. The nearby cluster stars have spectral types and inferred absolute magnitudes which confirm the distance (and thus luminosity) estimate for LBV 1806-20. If we drop kinematic measurements of the distance ($15.1^{+1.8}_{-1.3}$ kpc), we have a lower limit on the distance of > 9.5 kpc, and on the luminosity of $> 2 \times 10^6 L_\odot$, based on the cluster stars. If we drop both the kinematic and cluster star indicators for distance, an ammonia absorption feature sets yet another lower limit to the distance of > 5.7 kpc, with a corresponding luminosity estimate of $> 7 \times 10^5 L_\odot$ for the candidate LBV 1806-20. Furthermore, based on very high angular-resolution speckle images, we determine that LBV 1806-20 is not a cluster of stars, but is rather a single star or binary system. Simple arguments based on the Eddington luminosity lead to an estimate of the total mass of LBV 1806-20 (single or binary) exceeding $190 M_\odot$. We discuss the possible uncertainties in these results, and their implications for the star formation history of this cluster.

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The 2003 Shell Event in eta Carinae

Patricia A. Whitelock (South African Astronomical Observatory), Michael W. Feast (University of Cape Town), Freddy Marang (SAAO), Elme Breedt (UCT)

Near-infrared, JHKL, photometry of eta Car is reported covering the period 2000 to 2004. This includes the 2003 shell event which was the subject of an international multi-wavelength campaign. The fading that accompanied this event was similar to, although slightly deeper than, that which accompanied the previous one. The period between these events is 2023+/-3 days and they are strictly periodic. Their cause, as well as that of the quasi-periodic variations and secular brightening are discussed. It seems possible that all three types of variability are consequences of the binary nature of the star.

To appear in MNRAS
`astro-ph/0404513`

Rotation of Early B-type Stars in the Large Magellanic Cloud – The role of evolution and metallicity

Stefan C. Keller

I present measurements of the projected rotational velocities of a sample of 100 early B-type main-sequence stars in the Large Magellanic Cloud. This is the first extragalactic study of the distribution of stellar rotational velocities. The sample is drawn from two sources: a sample derived from the vicinity of the main-sequence turnoff of young clusters (ages $1 - 3 \times 10^7$yrs), and a sample from the general field. I find the cluster population exhibits significantly more rapid rotation than that seen in the field. I have drawn analogous Galactic cluster and field samples from the literature. Comparison of these samples reveals the same effect. I propose the observed difference between cluster and field populations can be explained by a scenario of evolutionary enhancement of the surface angular momentum over the main-sequence lifetime. A comparison is made between the cluster and field populations of the LMC and the Galaxy in order to explore the effects of metallicity. This shows that the LMC stars are more rapid rotators than their Galactic counterparts.

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`astro-ph/0405129`

WX Cen (= WR 48c) - a possible type Ia Supernova progenitor

Alexandre S. Oliveira, J. E. Steiner (IAG-USP, Brasil)

We confirm the orbital period of WX Cen (WR 48c) determined by Diaz & Steiner (1995) and refined its value to P = 0.416 961 5 d. The light curve of this object has an amplitude of 0.32 magnitudes and has a V-shaped narrow minimum, similar to the ones seen in V Sge, V617 Sgr and in Compact Binary Supersoft Sources - CBSS. The He II Pickering series decrement shows that the system has significant amount of hydrogen. The He II 4686 emission lines became weaker between the 1991 and 2000/2002 observations, indicating distinct levels of activity. The Balmer lines show variable features with V = -2900 km/s in absorption and with V = +/- 3500 km/s in emission. These highly variable events remind the satellites in emission of CBSS. We estimate the color excess as E(B-V)=0.63. Given the distance-color excess relation in the direction of WX Cen, this implies a distance of 2.8 kpc. Interstellar absorption of the Na I D lines show components at -4.1 km/s, which corresponds to the velocity of the Coalsack, and three other components a -23.9, -32.0 and -39.0 km/s. These components are also seen with similar strengths in field stars that have distances between 1.8 and 2.7 kpc. The intrinsic color of WX Cen is (B-V)0=-0.2 and the absolute magnitude, Mv = -0.5. Extended red wings in the strong

emission lines are seen. A possible explanation is that the system has a spill-over stream similar to what is seen in V617 Sgr. We predict that when observed in opposite orbital phase, blue wings would be observed. The velocity of the satellite-like feature is consistent with the idea that the central star is a white dwarf with a mass of M   0.9 Msun. With the high accretion rate under consideration, the star may become a SN Ia in a time-scale of 5×10^6 years.

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Submitted Papers

A Porosity-Length Formalism for Photon-Tiring-Limited Mass Loss from Stars Above the Eddington Limit

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We examine radiatively driven mass loss from stars near and above the Eddington limit. Building upon the standard CAK theory of driving by scattering in an ensemble of lines with a power-law distribution of opacity, we first show that the formal divergence of such line-driven mass loss as a star approaches the Eddington limit is actually limited by the "photon tiring" associated with the work needed to lift material out of the star's gravitational potential. We also examine such tiring in simple continuum-driven models in which a specified outward increase in opacity causes a net outward acceleration above the radius where the generalized Eddington parameter exceeds unity. When the density at this radius implies a mass loss too close to the tiring limit, the overall result is flow stagnation at a finite radius. Since escape of a net steady wind is precluded, such circumstances are expected to lead to extensive variability and spatial structure. After briefly reviewing convective and other instabilities that also can be expected to lead to extensive structure in the envelope and atmosphere of a star near or above the Eddington limit, we investigate how the *porosity* of such a structured medium can reduce the effective coupling between the matter and radiation. Introducing a new "*porosity-length*" formalism, we derive a simple scaling for the reduced effective opacity, and use this to derive an associated scaling for the porosity-moderated, continuum-driven mass loss rate from stars that formally exceed the Eddington limit. For a simple super-Eddington model with a single porosity length that is assumed to be on the order of the gravitational scale height, the overall mass loss is similar to that derived in previous porosity models, given roughly by L_*/a_*c (where L_* is the stellar luminosity, and c and a_* are the speed of light and atmospheric sound speed). This is much higher than is typical of line-driven winds, but is still only a few percent of the tiring limit. To obtain still stronger mass loss that approaches observationally inferred values near this limit, we draw upon an analogy with the power-law distribution of line-opacity in the standard CAK model of line-driven winds, and thereby introduce a *power-law-porosity* model in which the associated structure has a broad range of scales. We show that, for power indices $\alpha_p < 1$, the mass loss rate can be enhanced over the single-scale model by a factor that increases with the Eddington parameter as Γ^{-1+1/α_p}. For lower α_p ($\approx 0.5 - 0.6$) and/or moderately large Γ ($> 3 - 4$), such models lead to mass loss rates that approach the photon tiring limit. Together with the ability to drive quite fast outflow speeds (of order the

surface escape speed), the derived, near-tiring-limited mass loss offer a potential dynamical basis to explain the observationally inferred large mass loss and flow speeds of giant outbursts in η Carinae and other Luminous Blue Variable stars.

Submitted to Astrophysical Journal
Preprints from owocki@bartol.udel.edu
or on the web at http://www.bartol.udel.edu/~owocki/preprints/powlaw-porosity.pdf

The Effect of Rotational Gravity Darkening on Magnetically Torqued Be Star Disks

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In the magnetically torqued disk (MTD) model for hot star disks, as proposed and formulated by Cassinelli et al. (2002), stellar wind mass loss was taken to be uniform over the stellar surface. Here account is taken of the fact that as stellar spin rate S_o $(= \sqrt{\Omega_o^2 R^3/GM})$ is increased, and the stellar equator is gravity darkened, the equatorial mass flux and terminal speed are reduced, compared to the poles, for a given total $M_\odot$ yr^{-1}. As a result, the distribution of equatorial disk density, determined by the impact of north and southbound flows, is shifted further out from the star. This results, for high S_o ($\gtrsim 0.5$), in a fall in the disk mass and emission measure, and hence in the observed emission line EW, scattering polarization, and IR emission. Consequently, contrary to expectations, critical rotation $S_o \rightarrow 1$ is not the optimum for creation of hot star disks which, in terms of EM for example, is found to occur in a broad peak around $S_o \approx 0.5 - 0.6$ depending slightly on the wind velocity law.

The relationship of this analytic quasi-steady parametric MTD model to other work on magnetically guided winds is discussed. In particular the failures of the MTD model for Be-star disks alleged by Owocki & ud-Doula (2003) are shown to revolve largely around open observational tests, rather in the basic MTD physics, and around their use of insufficiently strong fields.

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Preprints from john@astro.gla.ac.uk(JCB); li@astro.gla.ac.uk(QL)

Clumping - Not the Solution to the Wolf-Rayet Wind Momentum Problem?

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The hot star wind momentum problem is revisited, and it is shown that the conventional belief, that it can be solved by a combination of clumping of the wind and multiple scattering of photons, is not self-consistent. Clumping does reduce the mass loss rate $M_\odot$ yr^{-1}, and hence the momentum supply, required to generate a specified radio emission measure ε, while multiple scattering increases the delivery of momentum from a specified stellar luminosity L. However, when combined the two effects act in opposition rather than in unison since clumping reduces multiple scattering. From basic geometric considerations, it is shown that this reduction in momentum delivery by clumping more than offsets the reduction in momentum required, for a specified ε. Thus the ratio of momentum deliverable to momentum required is maximal for a smooth wind and the momentum problem remains.

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In Proceedings

Stellar Wind Mechanisms and Instabilities

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I review driving mechanisms for stellar winds, using first the example of the coronal, pressure-driven solar wind, but then focussing mainly on radiation-pressure driven winds from hot, luminous stars. For the latter, I review the central role of line-opacity as a coupling between matter and radiation, emphasizing how the Doppler shift of an accelerating wind outflow exposes the strong line opacity to a substantial continuum flux, and thus allows the line force to sustain the outward acceleration against gravity. Through the CAK formalism that assumes a power-law distribution of line-opacity, I derive the mass loss rate and wind velocity law, and discuss how these are altered by various refinements like a finite-disk correction, ionization variations in opacity, and a non-zero sound speed. I also discuss how multiline scattering in Wolf-Rayet (WR) winds can allow them to exceed the single scattering limit, for which the wind and radiative momenta are equal. Through a time-dependent perturbation analysis, I show how the line-driving leads to a fast, inward "Abbott-wave" mode for long wavelength perturbations, and a strong Line-Deshadowing-Instability at short wavelengths, summarizing also 1D and 2D numerical simulations of the nonlinear evolution of this instability. I next discuss how rapid stellar rotation alters the latitudinal variation of mass loss and flow speed, and how this depends on treatment of gravity darkening, nonradial line forces, and "bi-stability" shifts in ionization. Finally, I conclude with a discussion of the large mass loss epochs of Luminous Blue Variable (LBV) stars, and how these might be modeled via super-Eddington, continuum driving moderated by the "porosity" associated with extensive spatial structure.

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