THE $\mathrm{H}\,\mathrm{O}^{\mathrm{T}}$ STAR NEWSLETTER

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

ed. Philippe Eenens

No. 10

eenens@tonali.inaoep.mx

June 1995

http://www.inaoep.mx/∼eenens/hot.html

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Accepted

The chemical enrichment by massive stars in Wolf-Rayet galaxies

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We present stellar population models for starbursts in a sample of eleven Wolf–Rayet galaxies. Taking into account the observational data available, we try to reconstruct the number of Wolf–Rayet stars observed and estimate the number of type II supernovae that have exploded in the ionizing cluster. Using the stellar yields of the most recent stellar evolutionary models for massive stars, we derive the expected chemical enrichment in helium, oxygen and nitrogen produced by the burst on the surrounding ionized gas. The results of this modelling indicate that since the helium and nitrogen production accounts for a fraction of the total content of the H II regions in these elements –implying the ocurrence of previous star formation events in the history of the parent galaxies–, the oxygen appears strongly overproduced in most of the objects. This fact and the correlation between the supernova rates derived for the bursts and their corresponding oxygen overproduction as well as the large volume filling factors expected for the hot gas that fills the supernova remnants, suggest the action of differential mass loss from the H II regions that could lead to galactic winds. We find that the chemical evolution of WR galaxies in the Y vs. N/H diagram appears to run parallel to the fit of the observational data for "normal" H II galaxies obtained by Pagel et al. (1992). Moreover, the pollution by the present–day population of Wolf–Rayet stars is unable to explain the apparently

abnormal position of some Wolf–Rayet galaxies on that diagram. We find that the effect of temperature fluctuations in the determination of the electron temperature of the ionized gas probably due to the presence of shocks could be an alternative explanation for this problem.

Accepted by A&A *For preprints, contact* cel@ll.iac.es

Kinematical study of ring nebulae around galactic Wolf-Rayet stars

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High resolution spectroscopic observations have been obtained for the ring nebulae around the galactic Wolf-Rayet stars WR113 (CV Ser), WR116, WR128 (MR95), WR133, WR134 (MR100) and WR153 using an echelle spectrograph. Gaussian fit analysis of the emission lines has been performed to establish the dynamical classification of the objects as well as to study their ionization structure and excitation mechanism. New wind blown bubbles have been discovered around WR116 and WR133 with expansion velocities of 50 and 25 km s^{-1} respectively. The nebulae around WR113 and WR153 are classified as shell-structured R_s objects due to the absence of clear evidence of expanding motions in the line profiles. The nebula associated with WR128 is confirmed as R_s-type as in previous works, and its spectrum seems to be consistent with photoionization as the main excitation mechanism without evidence of shock contribution. The complex velocity field of the emitting gas around WR134 has been analysed. We have studied the ionization structure and compared the kinematical data with the results of previous work in order to determine the nature of each velocity component. Finally, kinematic distances of the objects have been derived and compared with previous photometric distances obtained for the central stars.

Accepted by A&A *For preprints, contact* cel@ll.iac.es

Variability of Luminous Blue Variables II: Parameter study of the typical LBV variations

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We present predicted photometric and spectroscopic variations for Luminous Blue Variables (LBVs) based on a computed grid of Non-LTE extended and expanding atmosphere models. The effects of (*i*) mass loss, (*ii*) terminal flow velocity, (*iii*) rate of acceleration of the flow, (*iv*) minimum wind temperature, (*v*) effective gravity, and (*vi*) underlying stellar radius are investigated.

We show that the characteristic variations in visual magnitude for LBVs of $\Delta V \simeq 1$ to 2 magn, which occur at constant luminosity and are therefore associated with a change in photospheric radius and temperature, can not be due to the formation of a 'pseudo' photosphere in the wind induced by a

dramatic increase in mass loss rate. This implies that the origin of the mechanism responsible for the variations is located below the atmosphere. The change in photospheric radius that can be achieved by changing the wind parameters (i) to (iv), using observed mass loss rates, is $\sim 40\%$. However, a change of a factor of 4 to 12, depending on luminosity, is needed to reach the observed minimum effective temperature of LBVs of $T_{\rm eff} \approx 8000$ K. We conclude that the observed increase in photospheric radius is due to the combined effect of an increase in the underlying stellar radius (vi) and a reduced effective gravity (v).

Our calculations further show that mass loss and velocity structure variations may in principle cause visual magnitude changes of $\Delta V \lesssim 0.2$ magn, however *only* if the optical depth of the wind is at the outset of the order of unity. To estimate the optical depth of the wind, we provide a simple formula.

We also show the sensitivity of the profiles of several H and He I lines to changes in the photospheric and wind parameters and explain the behaviour of Hα in simple physical terms.

Accepted by A&A *For preprints, contact* alex@homie.gsfc.nasa.gov

Long-term spectroscopic monitoring of BA-type supergiants I: Hα line-profile variability

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We have obtained time series of spectra in the wavelength range $4\,000 - 6\,800$ Å over several months with high S/N and high resolution in wavelength ($\lambda/\Delta\lambda \approx 20\,000$) and time ($\Delta t \approx 1$ d) of the late-type B and early-type A supergiants HD 91619 (B7 Ia), β Ori (B8 Ia), HD 96919 (B9 Ia), HD 92207 (A0 Ia), HD 100262 (A2 Ia) and α Cyg (A2 Ia). Hα is found to show broad emission extended to about ± 1200 km s^{-1} for all objects except α Cyg. Due to the lack of strong line-emission in Hα the electron-scattered photons are expected to originate in deep atmospheric layers. In all of the objects the Hα-line profiles are found to be highly variable on different time scales reaching from days to months. Patterns of variation in Hα are found to be quite symmetric about the systemic velocity and are mainly due to variable blue and red-shifted emission superimposed on almost constant photospheric and/or wind profiles. These V/R variations are interpreted in terms of axial symmetry of the envelopes of these objects. Time-series analyses of the variations reveal Hα time scales up to a factor of 6 longer than expected radial fundamental pulsation periods but consistent with rotational periods. Therefore, rotational modulation as a possible source of variability is concluded. Corotating weak magnetic surface structures are suggested as source for a rotationally modulated lower wind region. Suddenly appearing deep and highly blue-shifted absorptions in Hα are ascribed to instabilities of the ionization structure of the wind. Outwards propagating discrete absorption components have been observed only once in HD 92207.

Accepted by A & A *For preprints, contact* akaufer@lsw.uni-heidelberg.de
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The structure of Wolf-Rayet winds. I. Observation of ionization stratification in WR 6 and WR 111

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Although it is widely believed that the winds of Wolf-Rayet stars are driven by radiation pressure, a major problem has been to explain theoretically the observation of very efficient conversion of radiative momentum to the gas. Known as the 'momentum problem', this has led to alternative models in which the radiation force is only one of the forces acting on a W-R wind – others could be due to stellar rotation and a magnetic field, or result from stellar pulsation.

In a recent paper, Lucy & Abbott (1993) showed that radiation alone could drive the wind of WR 6 if strong ionization stratification in the wind causes sufficient line overlap so as to increase the momentum deposition via multiple scattering to the observationally required amount. Ionization stratification in an accelerated outflow should be observable as an inverse correlation of ionization potential with line width, and this has been noticed in a few stars in the literature. We here present multi-wavelength data sets which demonstrate observationally that the ionization in the winds of the two prototype stars of the WN and WC sequences, WR 6 (WN 5) and WR 111 (WC 5), decreases outward. We discuss how the data compare with the 'Standard Model' for these two stars.

Accepted by Ap. J. *For preprints, contact* rsl@binar.phyast.pitt.edu

Correlated variability in the X-ray and Hα emission from the O4If supergiant ζ Puppis

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The Position Sensitive Proportional Counter (PSPC) onboard the ROSAT satellite was used to monitor ζ Pup for 56651 seconds spread over 11 days in 1991 October. During the first 8 days, 592 high-resolution Hα profiles were also obtained simultaneously. In a detailed time series analysis we investigate the X-ray observations and the Hα line profiles for variability. We find a 1.44 c/d (cycles/day) modulation both in the Hα line profiles as well as in the X-ray band pass between 0.9 and 2.0 keV. Thus, our observations provide evidence for periodic variations in the wind density at the base of the wind of ζ Pup.

Accepted by A & A *For preprints, contact* thb@mpe-garching.mpg.de

WR 22 : The most massive Wolf-Rayet star ever weighed

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The results of an extensive spectroscopic campaign on the eclipsing binary WR 22 are presented. A new radial velocity curve is deduced for the WN7 component, allowing us to improve the parameters of the orbit, formerly determined on the basis of photographic spectra. The high signal-to-noise ratio of our data also allows the detection of some weak absorption lines which, for the first time, can definitely be attributed to the companion. A study of their radial velocities gives a mass ratio of $m_{\rm WR}/m_{\rm O} = 2.78$ leading to a minimum mass of $72\,{\rm M}_\odot$ for the WN7 star. The companion can be classified as a "late O" (O6.5-O8.5) star with a luminosity ratio of the system $q = L^y_{\rm WR}/L^y_{\rm O}$ at 5500 Å of about 8. The exceptionally high mass of the WN7 star and its high hydrogen mass-fraction suggest that WR 22 is at the beginning of its Wolf-Rayet evolution. As a matter of fact, with such a high mass, WR 22 most probably is still a hydrogen burning object. Therefore, the WN7 component is much closer to a main sequence O star with a "Wolf-Rayet clothing" than to the other members of the Wolf-Rayet family, which are rather highly evolved He-burning descendants of massive progenitors.

Accepted by A & A *For preprints, contact* rauw@astro.ulg.ac.be

The Peculiar Population of Hot Stars at the Galactic Center

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Br γ and Mg II 2.058 μm images of the Galactic center reveal that most of the Br γ emission is associated with interstellar gas but that the Mg II is largely concentrated on individual, luminous stars that therefore must be hot. High resolution spectra of these stars, emphasizing Mg II 2.058 μm through Br γ 2.166 μm, are compared with spectra of 98 hot, luminous stars from the literature and new spectra of 43 luminous galactic emission line stars including late nitrogen sequence Wolf-Rayet, Luminous Blue Variable, Oe, Of, and ON supergiant stars. Combining our data with other observations from the literature, the Mg II sources in the central parsec include ~ 5 Ofpe/WN stars and one late-WC star. The inferred luminosity and detection of Mg II emission lines in the spectrum of IRS 16NE make it a likely LBV candidate. However, we find 6 stars with line widths < 500 km/s which defy easy classification, even from the extensive library of comparison spectra we have compiled. Considering the ultraviolet constraints (cf. Serabyn & Lacy 1985; Shields & Ferland 1994) and the large number of peculiar hot stars, either we see this stellar population at a very distinctive moment in its evolution, or the conditions of formation or the evolution of the stars must be significantly altered by the environment in the central parsec.

Accepted by Ap J *For preprints, contact* ptamblyn@as.arizona.edu
or by ftp without fig.1: as.arizona.edu:pub/ptamblyn/peculiar

High Resolution Coronographic Imaging and Spectropolarimetry of the HR Carinae Nebula

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We present multi-color coronographic imaging and optical spectropolarimetry of the Luminous Blue Variable HR Car. The images reveal the presence, in both Hα and [NII] filters, of a filamentary nebula characterized by a bipolar, nearly point-symmetric structure, similar to some well known planetary nebulae. The nebular filaments, which extend to $18''$ from the star, appear to originate from an central brighter, compact structure which envelops HR Car, and has a size of $\sim 8''$. From the emission lines flux, we estimate the overall mass of ionized gas in the nebula to be $\sim$2.1 $M_\odot$. We also find evidence for the presence of intrinsic polarization in HR Car from the change of polarization at the Hα emission line with respect to the continuum. This result implies that the scattering material situated close to the star is not distributed with a spherical symmetry. From the Hα line-to-continuum vector we deduce an intrinsic polarization of (0.39$\pm$0.02)% with a position angle of (30$\pm$1)deg at Hα, and a large interstellar foreground polarization of (3.70$\pm$0.02)% with a position angle of (127.9$\pm$0.1)deg. HR Car is the third Luminous Blue Variable in which asymmetries of the circumstellar material on a small distance scale are found from spectropolarimetry to agree with the large scale morphology, revealed by coronographic imaging.

Accepted by A J *For preprints, contact* Nota@stsci.edu

Nebulae around Luminous Blue Variables: A unified picture

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The study of the nebulae around Luminous Blue Variables (LBVs) provides clues to the mass-loss history of massive stars before and during the LBV phase. In this paper we investigate the possibility that the LBV nebulae are shaped by interacting winds. We compare the morphologies of all known nebulae around LBVs, by compiling the results of our detailed coronographic imaging and spectroscopic studies of individual LBVs and their nebulae together with other relevant information from the literature. Most LBV nebulae exhibit axisymmetric morphologies, suggesting that a single basic formation mechanism is involved. We propose that a model which consists of a stellar wind interacting with a pre-existing density contrast (between the equatorial and polar directions) can explain most observed morphologies. There are several mechanisms which can produce the necessary density contrast and at present it is difficult to determine definitively whether one or more of these mechanisms have been operating in the different systems.

Accepted by Ap J *For preprints, contact* Nota@stsci.edu

Submitted

The dense galactic starburst NGC 3603. I. HST/FOS spectroscopy of individual stars in the core

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We present spectrograms of 14 individual luminous stars in HD 97950, the core ($r \leq 4'' = 0.12pc$) of the dense galactic starburst NGC 3603, obtained with the *Faint Object Spectrograph* aboard the refurbished *Hubble Space Telescope*. In a volume of less than a cubic light-year, 3 luminous hydrogen-rich WNL+abs stars cohabit with six O3 stars (including two O3 III (f*)) and other early O stars; HD 97950 is therefore the densest concentration of very massive stars known in the Galaxy. The close physical association between O3 and WNL + abs stars, as well as the evolution of spectroscopic features, suggests a direct evolutionary link between them. The total output of Lyman continuum photons from these 14 stars alone accounts for more than 75% of what is required to ionize the surrounding nebula. The very small radius of the wind-driven bubble surrounding HD 97950 seems at odds with the tremendous power, $L_w \sim 3.2 \times 10^{38}$ erg s^{-1}, supplied by massive stars to the nebula.

Submitted to A J *For preprints, contact* ldrissen@phy.ulaval.ca
A postscript file of the manuscript can be obtained via WWW at http://astrosun.phy.ulaval.ca/pub.html

Hot, Luminous Stars in Selected Regions of NGC 6822, M 31, and M 33

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We investigate the massive star content of the three Local Group galaxies NGC 6822, M 31, and M 33 using crowded-field CCD UBV photometry in selected regions to identify the most luminous and massive stars. Optical spectral types are presented for many of these stars, allowing construction of accurate H-R diagrams and the first meaningful characterization of the massive star populations in these galaxies. The spectral types also allow investigation of the internal reddenings within these systems and provide fine candidates for stellar-wind studies in the UV. The early-type stars identified include O-type in all three systems, and we call attention to a new Luminous Blue Variable candidate in M 33. Our spectroscopy of extreme B supergiants ($M_V = -7.5$) shows the expected changes with metallicity in comparison to similar objects in the Milky Way, LMC, and SMC, although the metal lines in the NGC 6822 stars are considerably weaker than that expected for a metallicity intermediate between that of the LMC and SMC, suggesting that this galaxy is more metal-poor than reddening within all three galaxies, including even the dwarf irregular NGC 6822, where the color excesses show a systematic spatial trend from $E(B-V) = 0.26$ near the edges to 0.45 in the middle. The slope of

the reddening curve is normal in NGC 6822 and M 33, with $E(U-B)/E(B-V) \approx 0.72$, but in M 31 we find that this ratio is 0.4-0.5 in all three of our fields.

We spectroscopically confirm that stars of high mass ($> 80\mathcal{M}_{\odot}$) and luminosity ($M_{bol} \approx -11$) are found in M 31 and M 33. (These stars are several magnitudes more luminous than those described by Herrero et al. 1994 as "the most luminous" members of these two galaxies.) We have not found stars of similar high mass or luminosity in NGC 6822, where the most luminous star present has $M_{bol} = -10$ and an inferred mass of 60 $\mathcal{M}_{\odot}$. Similarly, none of the OB associations in NGC 6822 are as impressive in terms of the number of massive stars as the rich associations of the Milky Way and Magellanic Clouds. However, OB 78 (=NGC 206) and OB48 in M 31 both contain 9-15 stars of mass $> 40\mathcal{M}_{\odot}$, making them comparable to impressive sites of star formation in the Milky Way and Magellanic Clouds. M 33 contains regions that are even more extreme, with M33-OB127 and M33-OB21 containing 20-30 such stars. The low number of very massive stars in NGC 6822 is consistent with the overall star-formation rate inferred by other means, but the M 33 results suggest that the formation of high-mass stars may be favored. The massive star content of individual associations would not have been inferred on the basis of Hα flux, meaning that the nebulae associated with a number of these OB associations are density rather than radiation bounded, probably due to holes blown in the H I.

We have also found that the ratio of the number of very massive ($> 40\mathcal{M}_{\odot}$) stars to the number of WR stars is constant within all the Local Group galaxies we have studied, suggesting that (a) the effect of metallicity on the evolution of massive stars is subtle if present, and (b) that WR stars make excellent tracers of the massive star populations. The fact that this ratio is roughly 3, rather than the 10 expected given the relative H- and He-burning lifetimes, argues that either our samples are (uniformly?) incomplete or that some fraction of WR stars are H-burning objects.

Submitted to A J
Preprints will be available after the referring process is complete.

Equatorial Wind-Compression Effects Across The H-R Diagram

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We investigate the degree to which moderate stellar rotation rates can influence the two-dimensional density structure in the winds of four classes of stars: Wolf-Rayet, B[e], Asymptotic Giant Branch (AGB), and nova. These classes are distributed across the H-R Diagram and have a wide range in escape speeds and wind acceleration. Futhermore, all have members which possess asymmetric circumstellar nebulae. It has been suggested that these asymmetries could result from stellar winds that have moderate equatorial density enhancements. Large enhancements may arise as the result of stellar rotation as demonstrated by the Wind-Compressed Disk (WCD) model of Bjorkman & Cassinelli (1993). Instead of a dense disk, here we consider a milder distortion called a Wind-Compressed Zone (WCZ) that can arise from rotation rates smaller than the disk formation threshold. A WCZ is said to occur if the density at the equator is 3 times that at the pole. We assume that the stellar winds obey a standard β-velocity law and consider the effects of varying two of the velocity law parameters: the terminal velocity, v_{∞}, and the exponent, β. For a given rotation rate, the wind-compression is enhanced as either v_{∞} is decreased, or β is increased, because both correspond to a smaller acceleration of the wind. A general result from our model simulations is that the asymptotic density and flow structure are predominantly governed by the ratio $\omega/\omega_{\rm D}$, where ω is the stellar rotation rate

normalized to the critical speed, and ω_D is the threshold value needed for disk formation. For the Wolf-Rayet and B[e] models, which have moderate wind terminal speeds and shallow velocity laws ($\beta = 3$), a WCZ can form even at rotation rates of order 10% and 20% critical, respectively. For the AGB model, which has a low terminal speed and a steep velocity law ($\beta = 0.5$), a WCZ can form at 35% critical. Finally, we consider novae, which have time-variable wind properties. In particular the location of the sonic point is time-dependent, so we compute models with a range of sonic point radii. In favorable cases a WCZ can form for white dwarf rotation rates of less than 20% critical; however, further work will be required to properly treat the extended subsonic region of nova winds.

Submitted to Ap J *For preprints, contact* rignace@jerry.sal.wisc.edu

Periodic Variations in UV Spectral Lines of the B0.5 Ib Star HD 64760: Evidence for Corotating Wind Streams Rooted in Surface Variations

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We discuss recently observed periodic modulations in the UV wind lines of the B-type supergiant HD 64760, with a focus on the peculiar, upwardly bowed shape seen in isoflux contours of the absorption variations plotted versus velocity and time. We show this qualitative impression of bowed contours is quantitatively confirmed by a peak in the phase for the associated periodic variation at very nearly the same line position as the apparent bow minimum. The bowed shape is significant because it indicates wind variations evolve both blueward and *redward*, i.e., toward both larger and *smaller* line-of-sight velocities. We show here, however, that these characteristics arise naturally from absorption by strictly *accelerating* corotating wind streams seen in projection against the stellar disk. The quite good agreement obtained with the observed profile variations provides strong evidence for corotating stream modulations in this wind, possibly induced by nonradial pulsations.

Submitted to Ap. J. Letters. *For preprints, contact* cranmer@bartol.udel.edu

EUVE Spectroscopy of β Canis Majoris (B1 II-III) from 500 to 700 Å

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Observations of the bright variable star β CMa (B1 II-III) made with the Extreme Ultraviolet Explorer (*EUVE*) are presented. We report on the continuous energy distribution, photospheric line identification, and the variability of the star, as well as the physical implications for the structure of the local interstellar medium. The star is one of the strongest EUV sources in the long wavelength spectrometer of *EUVE*, and one of only two early-type stars whose photospheric continuum was detected by the *EUVE* spectrometers. This paper is primarily concerned with the portion of the spectrum that lies between the neutral helium ionization edge at 504 Å and an effective cutoff by interstellar absorption near 700 Å. As in our EUV analysis of the B2 II star ϵ CMa, we found that line-blanketed model atmospheres are not capable of predicting an energy distribution which matches observations in all wavelength regions. Consequently, we derived two set of basic parameters for the star (T_{eff}= 24,800 K, log g =3.7; and T_{eff}= 23,250 K, log g =3.5), depending whether we accept the measured angular diameter, or require an exact agreement between models and the observed visual flux. For the higher T_{eff} model, the predicted EUV flux is in agreement with observations, while for the the lower T_{eff} the star's EUV continuum is about 5 times brighter than the predictions. In either case, the star does not show the order of magnitude EUV excess that was seen in ϵ CMa. The *EUVE* data also provide information concerning the low density interstellar medium in the direction of β CMa. We derive a neutral hydrogen column density of $\sim 2 \times 10^{18}$ cm^{-2} and estimate a lower limit for the neutral helium column density of 1.4×10^{18} cm^{-2}. The *EUVE* spectrum shows many strong photospheric absorption features, similar to that of ϵ CMa. Evidence for a stellar wind is seen in the O^5 630 Å absorption feature.

There is special interest in β CMa because it is among the brightest of the β Cephei class of variables. The pulsations in this class of star manifest themselves primarily as periodic effective temperature changes. We find that the semi-amplitude of the change is 108^{+31}_{-32} K for the primary period. This result is consistent with that derived from an analysis of the UV continuum by Beeckmans & Burger (1977), but our error bars are significantly smaller. The general agreement implies that the pulsations do propagate between the layers where the optical and UV continua are formed and the layers where the EUV continuum forms, which is about six density scale heights higher in static models. The possibility that some pulsational energy deposition could occur within the outer photosphere is discussed. Our observations, taken over two time intervals separated by 70 days, resulted in the detection of the beat phenomenon owing to the three oscillation periods of β CMa.

Submitted to Ap.J. *Preprints may be obtained via anonymous ftp to* uwast.astro.wisc.edu; *cd to* outgoing/cohen/bcma_paper

The Importance of Radiative Braking for the Wind Interaction in the Close WR+O Binary V444 Cygni

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We describe radiation-hydrodynamical simulations of the wind interaction in the close WR+O binary V444 Cygni, with special emphasis on the potential role of the O-star light in decelerating the ap-

proaching massive WR wind. We demonstrate that such *radiative braking* can significantly alter the strength and overall geometry of the wind interaction, leading, for example, to a substantially wider opening angle for the wind bow shock. It can also cause the X-ray production to fall far below previous theoretical estimates based on collision of the two winds at their terminal speeds.

In addition, we find that the importance of radiative braking in this system depends crucially on the effectiveness of the WR wind line-opacity in reflecting O-star light. This suggests that observational estimates of quite gross system characteristics, like the bow-shock opening angle, can be used to infer the degree of radiative braking, and so provide a useful new contraint for line-driving models of WR winds.

Submitted to Ap J *For preprints, contact* gayley@bartol.bartol.udel.edu

Reviews

Population I stellar structure and evolution: facing the lingering difficulties to make a step forward

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We examine the various discrepancies between models of stellar evolution and observations. In particular, a brief review is made on 1) the extended cluster main sequence, 2) the N/C and $^{13}C/^{12}C$ enrichments on the Red Giant Branch, 3) the abundances in Cepheids and AGB stars, 4) the helium and N-excesses in OBA supergiants, 6) the blue Herzsprung gap and the ledge, 7) the ratios B/R of blue to red supergiants in galaxies, 8) the WR stars. We emphasize that the various comparisons made tend to favor some additional mixing, possibly related to rotation. It is likely that for given mass M and metallicity Z, one no longer has a single evolutionary track, but a family of tracks depending on the rotational velocity. We conclude that the collected discrepancies demand a new generation of stellar evolutionary models.

To appear in Stellar Pulsations, IAU Coll. 155, Ed. R. Stobie, Kluwer Acad. Publ., in press
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EUV Radiation from B-stars: the Broad Implications for Stellar and Interstellar Astronomy

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Observations made with the Extreme Ultraviolet Explorer of the two bright stars ϵ CMa (B2 II) and β CMa (B1 II-III) are discussed. The photospheres show excess EUV radiation. The wind of ϵ CMa exhibits the Bowen Fluorescence mechanism, along with high ionization stages that help explain the nature of the wind shocks. The pulsation and beat phenomena exhibited by the variable star β CMa suggest that deposition of residual pulsation energy might heat and modify the structure of

the atmospheres of early-type stars near the β Cephei strip. The possibility that many other B stars show a large excess Lyman continuum radiation is considered as a possible source of the ionization of the warm ionized medium (WIM) in the galactic ISM.

To appear in IAU Colloquium 152 "Astrophysics in the Extreme Ultraviolet"
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EUV Radiation from Hot Star Photospheres: Theory versus Observations

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The only stars other than white dwarfs whose photospheric extreme ultraviolet radiation has been detected are ϵ and β CMa. It is therefore of considerable theoretical interest to compare the *EUVE* observations of these two giant B stars to predicted spectra. However, both LTE and non-LTE very sophisticated line blanketed model atmospheres fail to match the observed flux. This failure leaves the stellar photosphere theory, even for seemingly "simple" objects as normal B giants were believed to be, in a rather dubious position. This paper briefly summarizes possible reasons for the failure of existing models to describe the *EUVE* observations of hot stars. In particular, we discuss the effects of uncertainties in the line blanketing, and the effects of the photosphere–wind interaction.

To appear in IAU Colloquium 152 "Astrophysics in the Extreme Ultraviolet"
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Theses

Spectropolarimetry as a probe of stellar winds

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The use of spectropolarimetry as a diagnostic probe of stellar-wind structure is investigated by using high-quality observations and state-of-the-art analytical and numerical models.

The first detection of emission-line (Hα) polarization structure in an O supergiant (ζ Puppis) is presented. Model polarization spectra are computed using statistical equilibrium calculations and Monte-Carlo radiative transfer. It is demonstrated that the latitudinal wind density structure predicted by radiation-driven wind theory is incapable of producing the observed polarization signature.

Multi-epoch observations of the pathological WN star EZ Canis Majoris are presented. These observations enable the accurate determination of the interstellar polarization (ISP) vector. The reliability of techniques used to estimate the ISP is assessed using tests performed on numerical models. The observed variability of the continuum polarization is explained in terms of scattering off density inhomogeneities propagating through the stellar wind.

A spectropolarimetric survey of 15 galactic Wolf-Rayet stars is presented. Emission-line polarization structure is observed in four of the survey stars. These data are combined with results of similar surveys in order to determine the frequency of line polarization structure in galactic WR stars. Detailed analyses are performed on the the polarization spectra of the dust-producing WC star WR 137 and the WN6 star WR 134.

The winds of late-type giant stars are studied through the highly polarized 6830Å and 7088Å Raman-scattered emission lines that are observed in many symbiotic systems. A spectropolarimetric survey of 28 symbiotic stars is presented. A Monte-Carlo code is developed in order to aid interpretation of the lines and the parameter sensitivity of the Raman line polarization spectrum is investigated. It is demonstrated that the observed line polarization morphologies can be reproduced by using realistic physical parameters and that the line polarization structure is a powerful diagnostic of the cool stellar wind. The binary phase dependence of the line structure is studied with the aim of using multi-epoch observations to derive orbital parameters. The polarization spectrum of the symbiotic star BI Crucis is analyzed and discussed in relation to the geometry of its extended bipolar nebula.

Ph.D. degree awarded: 31 March 1995 *Thesis advisor:* Ian D Howarth
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Unified models for the analysis of massive hot stars atmospheres

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Within the framework of this thesis we have developed a new unified code for the study of hot stars atmospheres. The main problem when studying such stars is the presence of supersonic winds, produced by the enormous radiation field in the atmosphere. Because of the winds, the spatial extension of the atmosphere becomes very large, and spherical models are needed. At the same time, the Doppler frequency shifts produced by the velocity field have to be taken into account.

The code we have developed solves successfully both aspects. Among its characteristics, we can emphasize two: (*i*) the unified treatment for photosphere and wind, and also for the transition zone in between, what allows us to investigate the effect of the wind on photospheric lines and also makes possible that the program can be applied to a wide range of stellar parameters, and (*ii*) the atomic data input and treatment has been programmed, for the first time in hot stars atmospheres, in a very flexible way, allowing us to study the effects that can arise when different atomic models and/or cross-sections are used.

The formal solution we perform to obtain emergent fluxes is also totally new. Based on the co-moving frame formalism, we define two optical depth scales, one for continuum and the other for lines, which allows us to separate them. This separation is analytical and exact.

Using the model we have developed, we have made a study of the effect the different parameters have both on the atmospheric structure and the emergent line profiles.

Specially interesting has been the comparison between two different neutral helium atomic models, because it is the first time that such a study has been performed. Although non definitive, the results show the importance of the atomic model considered, even in the highest states, on the final solution.

Ph.D. degree awarded: June 9th 1995 *Advisors:* Artemio Herrero and Joachim Puls
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