THE IRON CURTAIN OF WC9 STARS

K.A. van der Hucht[1], P.S. Conti[2] and A.J. Willis[3]
[1]Space Research Laboratory, University of Utrecht
[2]Joint Institute for Laboratory Astrophysics, Boulder
[3]Department of Physics and Astronomy, UCL, London

ABSTRACT

High resolution ($\Delta\lambda \approx 0.1$Å) IUE spectra have been obtained of the two WC9 stars HD 164270 and HD 136488, covering the wavelength range λλ1150-2050. The former star shows P Cygni profiles indicating a stellar wind terminal velocity of $v_\infty \approx -1400$ km s^{-1}, and the latter $v_\infty \approx -1800$ km s^{-1}. A common feature in the spectra of both stars is narrow displaced absorptions due to Fe III (UV34) transitions arising from a metastable lower level. These features are displaced at sub-terminal velocities (-830 km s^{-1} for HD 164270 and -1030 km s^{-1} for Hd 136488) and are believed to be formed in the deceleration region of their stellar winds. The properties of these inferred Fe III circumstellar shells derived from these data are discussed.

INTRODUCTION

Recently, van der Hucht and Conti (1981) reported about a circumstellar iron curtain around the WC9 star HD 164270: a gas shell displaying UV Fe III absorption lines from transitions with metastable lower levels. It was concluded that this shell is located in the decelerating part of the stellar wind and has a radius of 84 AU. This size is of the same order of magnitude of the size derived for dust shells around WC9 stars (Cohen *et al.*, 1975).

The WC9 star next in apparent brightness is HD 136488. Both this star and HD 164270 show a thermal infrared excess which is caused by their dust shells and which is associated with a black body temperature $T_{bb} \approx 1400$ K (Cohen, 1975).

HD 136488 AND HD 164270

The WC9 star HD 136488 was observed with IUE at high resolution in spring 1981 (SWP 13816). Again, as in the case of HD 164270, narrow absorption lines of Fe III, from transitions with metastable lower levels, are superposed on the emission line spectrum. This means that the presence of metastable lines, which have to arise in a low density

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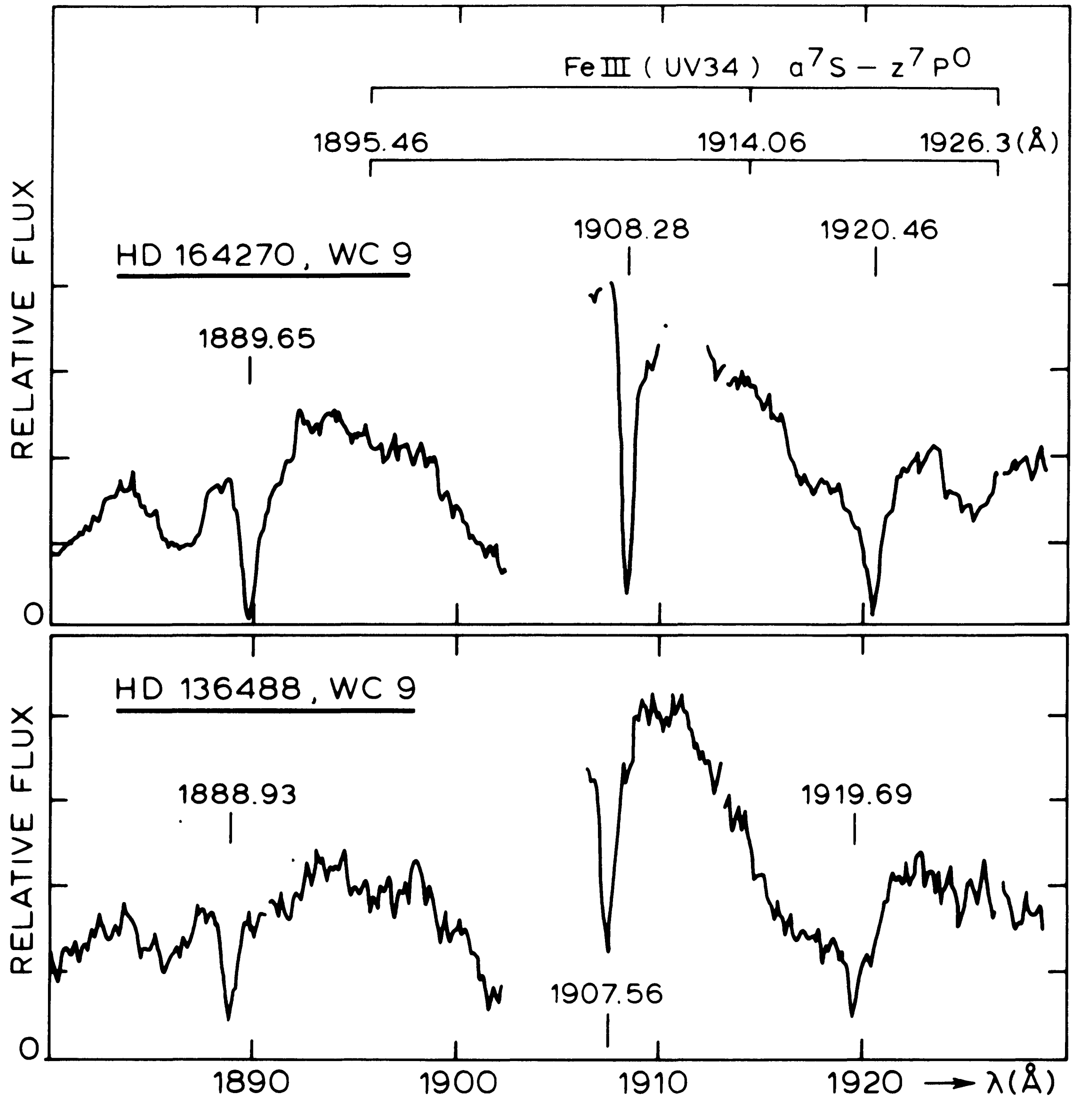

Fe III absorption lines in WC9 stars from transitions with meta-stable lower levels.

environment, is most likely a characteristic phenomenon for all WC 9 stars. The figure presents part of the observations of both HD 164270 and HD 136488. The line measurements are listed in Table 1. We note that for HD 136488 the Fe III lines are somewhat weaker and have a somewhat larger outward velocity than for HD 164270.

From P Cygni profiles in the spectra of the two stars we derive the corresponding terminal velocities of their stellar winds. An immediate result is that for both stars: $v_{Fe\ III}/v_\infty \approx 0.6$. The Fe III (UV34) lines in HD 136488 were analyzed in the same way as those of

Table 1. EQUIVALENT WIDTHS AND VELOCITIES

λ_{obs} (Å)	IDENTIFICATION				W_λ (Å)	$\Delta\lambda$ (Å)	v_{rad} (km s^{-1})
	λ_{lab} (Å)	EP_1 (eV)	Mult. No.	log gf			
HD 164270 =========							
1890.28	1895.46	3.71	34	+ 0.48	.880	- 5.18	- 820
1908.72	1914.06	3.71	34	+ 0.36	.810	- 5.33	- 835
1920.97	1926.30	3.71	34	+ 0.21	.800	- 5.33	- 830
HD 136488 =========							
1888.93	"	"	"	"	.550	- 6.53	- 1035
1907.56	"	"	"	"	.460	- 6.50	- 1020
1919.69	"	"	"	"	.350	- 6.61	- 1030

HD 164270 (van der Hucht and Conti, 1981) and the results are listed in Table 2. Radii and densities are calculated with the assumption that both stars have the same mass loss rate $\dot{M} = 4.1 \times 10^{-5}\ M_\odot\ yr^{-1}$. This is the value which Barlow *et al.* (1981) found for WC5-8 stars. A mass loss determination for WC9 stars is not yet available. We find for HD 136488 a larger shell radius with a consequently smaller shell density than for HD 164270. This is because HD 136488 has weaker Fe III absorption lines and a larger Fe III velocity than HD 164270.

DISCUSSION

It is significant that both stars have $v_{Fe\ III}/v_\infty \approx 0.6$ and that both have Fe III shell radii of the same order of magnitude as the WC9 circumstellar dust shell radii published by Cohen *et al.* (1975). The work of the latter has been confirmed recently by Allen *et al.* (1981) who found $R_{dust} \approx 82$ AU for the WC9 star Ve2-45 with speckle interferometry at 2.2 μm.

Apparently at this distance in the winds of WC9 stars, a breaking mechanism coupled with the presence or the formation of dust, is active, which brings the wind velocity down to 0.6 times its highest value.

Although it may be tempting to argue that the dust consists of carbon (graphite), Hackwell *et al.* (1979) found for the case of HD 193793 (WC7 + abs.) that its dust is iron. If this is also valid for WC9 dust shells, than the coincidence of the Fe III gas shell radius and the dust shell radius may be more than that. A further analysis is in progress.

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Table 2. PARAMETERS, MEASUREMENTS AND RESULTS*

		HD 164270	HD 136488
v		9.01	9.43
$b - v$		0.03	0.14
E_{b-v}		0.58	0.69
A_v		2.38	2.83
d	(kpc)	2.67	2.63
z	(pc)	− 228	− 221
$v_{Fe\ III}$	(km s^{-1})	− 830	− 1030
v_∞	(km s^{-1})	− 1400	− 1800
$v_{Fe\ III}/v_\infty$		0.59	0.57
v_D(Fe III)	(km s^{-1})	100	75
N_{Fe}	(cm^{-2})	3.4×10^{16}	1.3×10^{16}
N_{total}	(g cm^{-2})	1.9×10^{-3}	7.2×10^{-4}
$\frac{\dot{M}}{R_{Fe\ III}/R_\odot}$	$\left(\frac{M_\odot}{yr}\right)$	2.2×10^{-9}	1.0×10^{-9}
$R_{Fe\ III}$	($R_\odot$)	1.8×10^{4}	4.0×10^{4}
	(AU)	84	186
$n_{He}(R_{Fe\ III})$	(cm^{-3})	2.3×10^{5}	3.9×10^{4}

* *Catalogue information from van der Hucht et al. (1981). Extinction and distances from Hidayat et al. (1981).*

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DISCUSSION

Vanbeveren: In a paper which is published already in A&A, I have shown that based on the observed WN/WC number ratio, one can estimate the average $\dot{M}$ during core He-burning in order to explain this ratio. This average value was about 4×10^{-5} $M_{\odot}$/y (for WN and WC stars) which is very much in agreement with the values proposed by Barlow, Smith and Willis. You find a mass loss rate for WN stars which is almost the same, whereas the mass loss rate in WC stars is about twice as high. Now there are two possibilities: either on a very short timescale you lose your whole star, or one has to assume that the WR phase does not last for the whole core He-burning in this way producing a WN/WC ratio which is considerable larger.

van der Hucht: Since the WN/WC ratio is not constant with galactocentric distance (it is larger than 1 outside the solar circle and smaller than 1 within it), you should specify your result for different galactocentric distances. This is connected, of course, with the metallicity gradient in the Galaxy. I should add that theory should explain observations, not the other way around. (see Hidayat, Supelli and van der Hucht, these proceedings).

Nussbaumer: At densities of $N_e \sim 10^4-10^5$ cm^{-3} you cannot expect the lower level of your transitions to be in Boltzmann equilibrium. Did you account for this ?

van der Hucht: The level population ratios within Fe III are completely dominated by the radiation field of the star. Collissions have been ignored entirely in our calculations.

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