NARROW COMPONENTS IN UV LINE PROFILES AS EVIDENCE FOR A TWO COMPONENT STELLAR WIND FOR O AND B STARS.

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I. INTRODUCTION

The UV resonance lines of early type stars show narrow absorption components, with a width of the order of 300 km s^{-1}, superimposed on the wider P Cygni profiles. Such narrow components have been detected in the Copernicus spectra of a few early type stars by Morton (1976) and Snow and Morton (1979). The variability of these components was studied by Snow (1977) who compared two scans of the UV line profiles of 15 stars taken about four years apart. He found that the narrow components do not change in velocity (except for the CIII λ1175 line in ζ Pup) but that the strength of the components can change drastically. In some stars the narrow components were present in only one of the two spectra. We studied the characteristics of these narrow components in the Copernicus spectra (Snow and Jenkins, 1977). The stars are listed in Table 1. Examples of these narrow components are shown in Figure 1.

II. CHARACTERISTICS OF THE NARROW COMPONENTS

From a detailed study of the P Cygni profiles and of the narrow components the following characteristics were found:

i) the narrow component velocity is the same for different ions within one star;
ii) the narrow component velocity $\overline{v}_s/v_\infty$ is about 0.75 and independent of spectral type and luminosity class;
iii) the mean FWHM of the narrow components, F_s is about 0.19 v_∞.
iv) the hydrogen column density of the narrow components is typically of the order of 10^{21} to 10^{22} cm^{-2}.
v) the narrow components have a higher degree of ionization than the underlying P Cygni profile. In particular, the O VI/N V ration in the narrow components is about three times larger than in the P Cygni profile.

C. Chiosi and R. Stalio (eds.), Effects of Mass Loss on Stellar Evolution, 181–186.

TABLE 1. NARROW COMPONENTS IN UV RESONANCE LINES.

Star	Type	O VI	N V	Si IV	Si III	v_s (km/s)	v_s/v_∞
ζ Pup	O4 If						
9 Sgr	O4 V((f))						
HD 199579	O6 V((f))						
15 Mon	O7 V((f))	+	+			2000±130	0.65±.04
θ^1 Ori C	O7 V p	+					
ξ Per	O7.5 III((f))	+	++	++		2190±110	0.73±.02
						1860± 70	0.62±.02
λ Ori A	O8 III((f))	+	+			2020± 50	0.76±.02
τ CMa	O9 II	+	+			1930± 30	0.85±.01
i Ori	O9 III	+	+			2080± 10	0.88±.00
10 Lac	O9 V	+	+			900± 80	0.60±.05
α Cam	O9.5 Ia	++	+	++	+	1150± 20	0.56±.01
						1400± 40	0.68±.02
δ Ori A	O9.5 II	++	+	++	++	1830± 10	0.76±.00
ζ Oph	O9.5 V		+			1380± 40	0.87±.03
μ Col	O9.5 V	+				1000:	0.67:
μ Nor	O9.7 Iab	+				1880:	0.86:
ζ Ori A	O9.7 Ib	+	+	+	+	1620± 40	0.71±.02
ε Ori	B0 Ia	+				1480:	0.70:
τ Sco	B0 V						
κ Ori	B0.5 Ia	+		+		1430± 30	0.76±.02
ε Per	B0.5 III	+				1160±110	0.77±.07
δ Sco	B0.5 IV						
θ Car	B0.5 Vp						
ρ Leo	B1 Iab	+	+	++	++	1020± 50	0.65±.03
						1350± 80	0.85±.05
γ Ara	B1 Ib						
ζ Per	B1 Ib						
139 Tau	B1 Ib						

Remarks: + narrow component present; ++ more than one narrow component.

III. POSSIBLE EXPLANATIONS

a. Peaks in the degree of ionization. If the narrow components were due to an increase or decrease of the ionization balance with distance, one would expect a correlation between the velocity and the ionization potential. This does not agree with characteristic i, nor with detailed studies of a few stars which show that the degree of ionization is almost constant with height, or that it decreases very slowly.

b. A plateau in the velocity law of the wind at 0.75 v_∞.

A plateau in the velocity law would create a large column density at the plateau-velocity for all ions. This would agree with characteristic i. However, the strong time variations in the strength of the narrow components (Snow, 1977), and the appearance of narrow components at more than one velocity in some stars are arguments against this interpretation.

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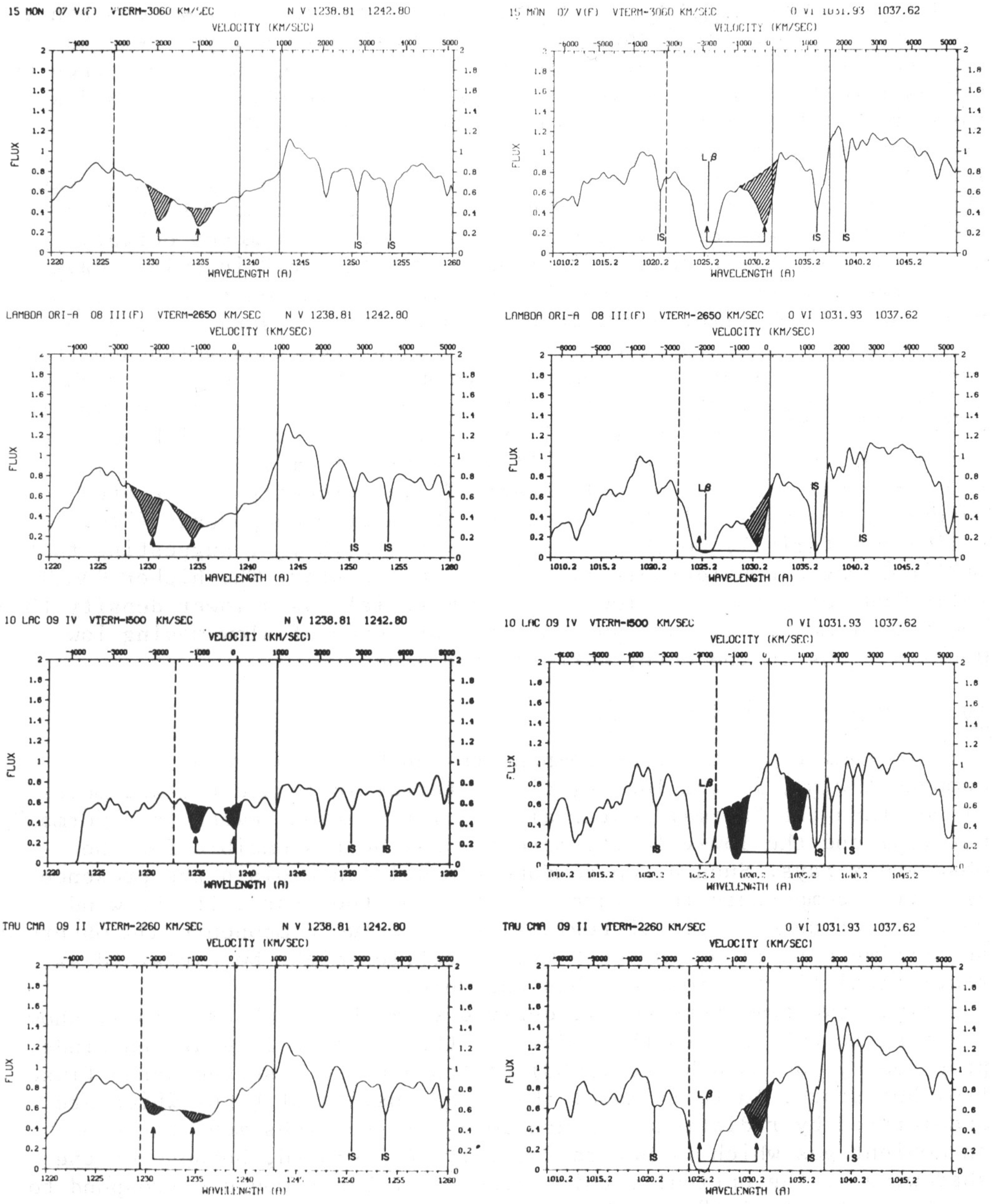

Figure 1. The presence of narrow components in the profiles of N V and O VI lines in four stars is shown. The full vertical lines indicate the rest wavelengths of the resonance lines. The dashed vertical lines indicates the terminal velocity for the short wavelength component. The arrows indicate the position of the narrow components, separated by the difference in rest wavelengths of the lines. The narrow component of the line O VI λ1031.93 coincides with the Lβ line in several stars. The location of strong interstellar lines, which can clearly be recognized on the original spectra, is indicated.

c. Narrow components due to variable mass loss. The narrow components might be due to ejected shells or puffs which have not yet reached the terminal velocity. The column density of an ejected shell decreases as r^{-2} as the shell moves outward. If the shells are observed at a distance $r_s > 100\ R_*$ (which they would reach in only 4 days), the original hydrogen column density must have been about $10^{25} - 10^{26}$ (characteristic iv). For mass loss rates of the order of $2.10^{-6} M_\odot$/yr, it would take about 10^2 days to form such a shell. On the other hand, the column density decreases very rapidly in time as the shell moves outward. At $10^2\ R_*$ the column density decreases by a factor 2 in only 2 days. The large discrepancy between the very long formation time and this very short decay time, would make it unlikely to observe strong shell components in many stars, contrary to the observations which show that narrow components are a common phenomenon in the UV spectra of OB stars.
d. A two-component stellar wind. The narrow components can be explained by assuming a two component stellar wind. The material which produces the P Cygni profiles occurs at all velocities from $v \simeq 0$ to v_∞, so this material (called "normal material") is evidently accelerated outwards. The material which produces the narrow components ("low velocity material") moves at a velocity $v \simeq 0.75\ v_\infty$, suggesting that it occurs at a considerable distance from the star. The higher O VI/N V ratio indicates that the low velocity material has a lower density than the normal material. This suggests the presence of slow moving low density blobs in the outer parts of the wind.

IV. SUMMARY AND CONCLUSIONS

In summary, the narrow components can be explained by a two-component wind, if the low-velocity material is less dense and moves slower than the "normal" material. The interaction beween the "normal" material and the low-velocity material may be responsible for the observed x-rays. Such a two-component model can explain the presence of narrow components in a large fraction of the stars. If the wind consists of an ensemble of regions of these two components, the observed short-time variations in the P Cygni profiles might be explained as statistical fluctuations of this ensemble.

This two-component model, derived from the UV observations, shows a strong resemblance to the model for the unstable line-driven winds proposed by Lucy and White (1980) to explain the observed x-ray fluxes from hot stars. In their model the wind consists of blobs which are accelerated by radiation pressure to v_∞. These blobs move through an ambient gas which is not radiatively accelerated, because of the shadowing by the optically thick blobs. The blobs would correspond to our "normal material", which produces the P Cygni lines, whereas the ambient gas would correspond to our "low-velocity material".

This interpretation of the narrow components is different from the one proposed by Henrichs et al.(1980) to explain the shell components in the Be star 59 Cyg. In the Be-stars the components are much narrower with smaller column densities and highly variable. For these stars the components are most likely due to shell or puff ejection. (For more details see paper of Lamers, Gathier and Snow, 1981, Ap. J.)

REFERENCES

Henrichs, H., Hammerschlag-Hensberge, G., Lamers, H.J.G.L.M., 1980 (these proceedings)
Lamers, H.J.G.L.M., Gathier, R., Snow, T.P. 1980, Ap. J. (Letters) in press
Lucy, L.B. and White, R.L. 1980, Ap. J. (in press)
Morton, D.C. 1976, Ap. J. 203, 386
Snow, T.P. 1976, Ap. J. 217, 760
Snow, T.P., Jenkins, E.B. 1977, Ap. J. Suppl. 33, 269
Snow, T.P., Morton, D.C. 1976, Ap. J. Suppl. 32, 429

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DISCUSSION

TARAFDAR: Is it possible that the narrow components originate in the shell formed by star interaction of the wind with a dense ($n \approx 10^4$ cm^{-3}) interstellar medium?

LAMERS: I do not think so. The predictions by Castor, McCray and Weaver suggest: a) that the velocity of the components of the interstellar bubble would be very small (whereas we observe the narrow components at ~1500 Km/s), b) that the column densities would be much smaller than 10^{21}-10^{22} cm^{-2}.

DUPREE: Many of your results are dependent on a collisionally dominated ionization equilibrium. In the condition of density and high mass flow found in these atmospheres, it is quite possible that substantial departures from ionization equilibrium can occur providing that a sufficiently large temperature gradient is present. Have you investigated the ionization equilibrium for these atmospheres?

LAMERS: Yes. The degree of ionization in the winds of normal early type stars is about constant with distance, so there is little evidence for large temperature gradients in the winds (apart from a possible thin corona close to the star). The density in the winds of OB supergiants is of the order of $n_e \approx 10^{10}$ to $10^{11} cm^{-3}$. For such densities the recombination time scales for OVI – OV and NV – NIV are very small and of the order of seconds only, as shown by e.g. Lamers and Morton (1976, Ap J Suppl 32, 715) and by Castor et al. (1976, Physique des mouvements dans les Atmospheres Stellaires, Nice Symposium, ed. R. Cayrel and M. Steinberg).

HOWARTH: Do the velocities of the sharp components remain constant in spectroscopic binaries?

LAMERS: This would be an interesting observations, but I do not know of observations of these narrow components in spectroscopic binaries.