C IV RESONANCE LINE PROFILES IN O STARS

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I. INTRODUCTION AND OBSERVATIONS

The S-019 experiment on Skylab (cf. Henize et al. 1975; "Paper I") recorded far UV spectra in about 160 4° x 5° fields, covering 10% of the sky, on 101 film with a 15 cm aperture objective-prism telescope. Several hundred early-type stars were observed in the vicinity of 1550 Å with a resolution between 3 and 4 Å, as well as thousands of stars at longer wavelengths and correspondingly lower resolution. An atlas of spectra for types O4 to B5 is illustrated in Paper I. That figure shows that the P Cygni profile is a characteristic of all supergiants earlier than B3 and main sequence stars earlier than O8.

Subsequent to the qualitative presentation of the S-019 UV spectra, we converted intensities to absolute fluxes. The flux calibration was determined by comparison of the S-019 spectral intensities (averaged over the appropriate wavelength interval) with the fluxes derived from the S2/68 experiment on the TD-1 satellite (Jamar et al. 1976) or the WEP on OAO-2 (Code and Meade 1976). Details of the calibration will be published elsewhere. The standard deviation of resulting calculated fluxes with respect to TD-1 or scaled OAO-2 fluxes is about 30% for SL2 and SL3 and 40% for SL4. The relative accuracy in energy distributions, i.e. after allowing for a mean scale error in each spectrum, is normally better than 15%.

Two examples of reduced and averaged S-019 spectra are shown in Figure 1. The fluxes are normalized to an essentially flat continuum level and plotted against a linear wavelength scale. In the present results, one can see quantitatively the pronounced luminosity effects. The two O9.5 stars are markedly different in this region of the spectrum. The Si IV resonance lines are present but weak in the dwarf σ Ori, while in the supergiant ζ Ori there is an extreme P Cygni profile with two absorption components. The C IV $\lambda\lambda$ 1548, 1551 resonance feature makes a transition from a photospheric absorption line to a profile characteristic of a thick, rapidly expanding envelope. Because of the blends on the short wavelength side and the probable saturation

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of the C IV absorption, however, it has not been possible to extract quantitative information on mass loss rates.

II. C IV PROFILES AND THE H-R DIAGRAM

By studying the behavior of the C IV resonance profile with respect to T_{eff} and M_{bol}, one can learn about the conditions under which mass loss occurs without knowing precise mass loss rates. To do this, we have constructed an H-R diagram in these coordinates with the C IV profiles displayed directly for a representative sample of stars. We have used MK temperature classifications as the basis for a homogeneous set of estimates of T_{eff} and B.C., while for absolute magnitudes we have drawn from numerous sources, using cluster or association determinations when available, then quantitative classification methods such as Hγ equivalent width, and finally the MK luminosity class as a last resort. The adopted correlations between T_{eff} and spectral class are based primarily on the work of Conti (1973) for the O stars and Code et al. (1976) for the B stars. MK types are drawn from Morgan and Keenan (1973), Hiltner, Garrison and Schild (1969), Lesh (1968), Walborn (1973), and Conti and Leep (1974).

In Figure 2 the fiducial mark for each spectrum (zero intensity, λ = 1549 Å) is plotted at our best estimate for the bolometric absolute magnitude and effective temperature, except where a slight shift was required to avoid crowding. For many O stars, we give both Walborn's and Conti and Leep's spectral classifications. The star ξ Per is an anomaly and we have chosen to plot it using a quantitative determination of M_V = -6.5 from Borgman and Blaauw (1964).

III. DISCUSSION

There is a clear trend in the C IV feature toward more fully developed P Cygni profiles at higher luminosities. We have published before (Paper I) a bolometric limit M_{bol} = -8.4 above which we see definite P Cygni emission at the C IV and Si IV lines. We can now add that there is at least a significant velocity shift in the C IV absorption down to $M_{bol} \simeq -7.7$. At lower luminosities, given our moderate resolution and slight uncertainty in fixing the wavelength scale, we do not see evidence in this ultraviolet region for significant mass flow, although Snow and Morton (1976) detected velocity shifts with Copernicus for stars as faint as M_{bol} = -6.0. Our results and Copernicus data both show, however, that major mass loss effects, substantial envelopes and "stellar hurricanes" (Weymann 1977), occur for all stars more luminous than -8.4 or about 1.5 x 10^5 $L_{\odot}$.

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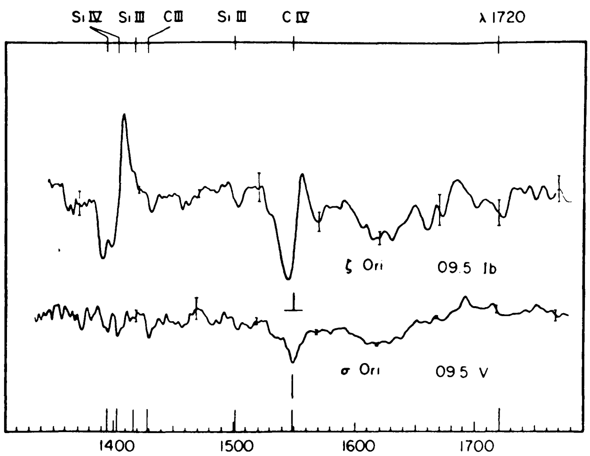

Figure 1. Normalized fluxes derived from objective-prism spectra. The zero point of the ζ Ori spectrum is indicated by the horizontal bar. Many differences in line strengths and profiles are evident.

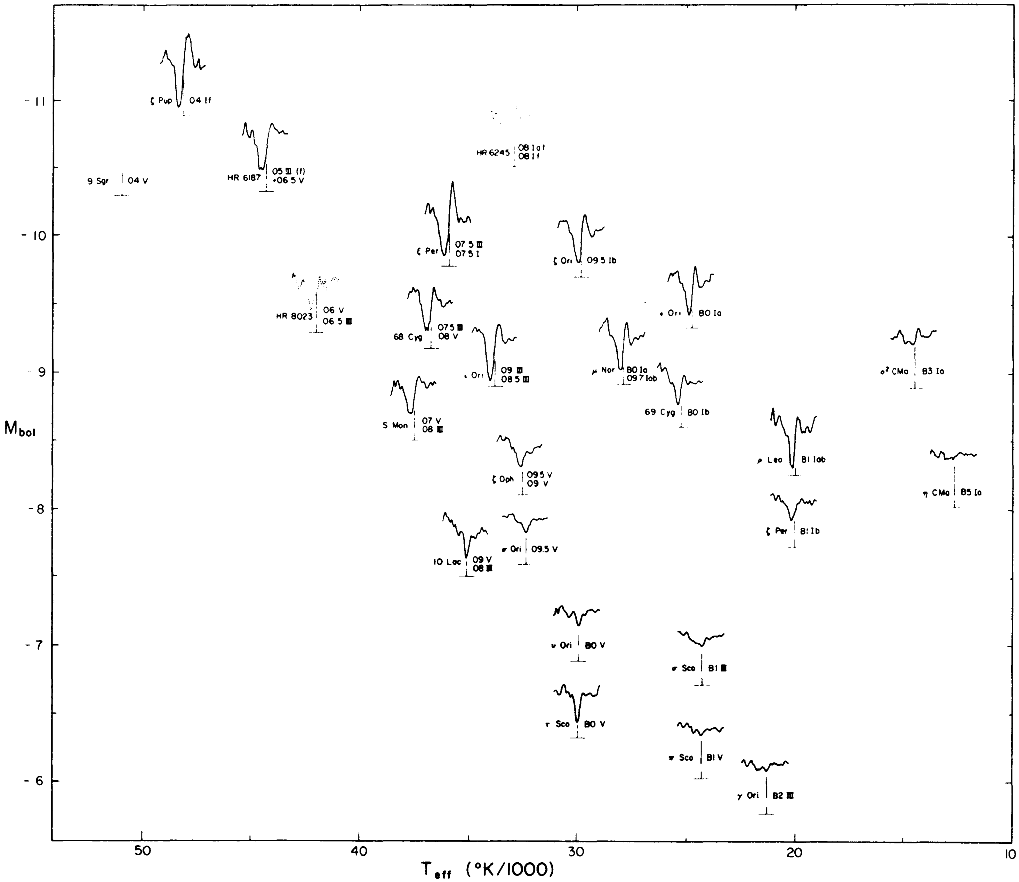

Figure 2. C IV profiles displayed with respect to estimated bolometric luminosities and effective temperatures of the stars. The interval 1507-1584 Å is extracted from plots of the type shown in Figure 1. The vertical bars indicate the rest position for the C IV resonance doublet.

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DISCUSSION FOLLOWING PARSONS et al.

Cassinelli: Are you aware of any observations of C IV in β Ori B8 Ia?

Parsons: We do have observations of β Ori but I don't recall any C IV. There is a definite C IV profile in o^2 CMa (B3 Ia) and just a hint of the profile in η CMa (B5 Ia).

Snow: What is your spectral resolution at the wavelength of the C IV doublet?

Parsons: It is in between 3 and 4 Å, depending slightly on the stability of the spacecraft.

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