Analysis of IUE spectrograms for Be stars

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Archival high-dispersion spectrograms obtained by the International Ultraviolet Explorer satellite in the short-wavelength (λλ1150-2000Å) region were inspected and analyzed for a total of 33 Be stars, including one Oe star (HR 6397) and three stars showing shell-type spectra in the optical region (48 Lib, ε Cap, o Aqr). The following atomic and ionic transitions were investigated: H II-Lyα, C II-UV1, C IIII-UV4, CIV-UV1, NV-UV1, Si III-UV1, SiIII-UV2, SiIV-UV1.

Measured line parameters include absorption equivalent widths, central line depths, full widths at half-maximum intensity, and short-wavelength edges for asymmetric profiles indicating the presence of a stellar wind. As far as possible, photospheric, circumstellar, and interstellar contributions to line absorption in these multiplets were identified according to their different line widths and evaluated separately. By means of curve-of-growth methods, column densities were derived for interstellar H I and Si II in the line of sight to program stars. H I column densities were then used to determine interstellar contributions to (B – V) colour excesses measured for these stars.

For Be stars showing shell-type spectra in the optical region, a strong circumstellar contribution to H I and Si III column densities is revealed by the appearance of Si III resonance absorption line transitions arising from excited fine-structure levels of its ground state (e.g., Si III λ1265, 1533, 1814 Å). Shell absorption in these Si III lines is also distinctly visible in one spectrum obtained for HR 4140 on 1980 January 23, but not in another one measured for the same star 1983 April 02. All these shell stars, including HR 4140, also show strong narrow absorption lines in the FeIII-UV34 multiplet (λ1895Å, 1914Å and 1926Å).

Photospheric absorption lines in the spectra of Be stars are characterized by strong symmetric broadening due to rapid rotation of the star. Equivalent widths measured for photospheric components of Si III, Si IIII and Si IV lines were compared to results of theoretical line strength predictions found in the literature (e.g., by Kamp (ApJ Suppl. 36, 143, 1978) and Lennon et al. (Mon. Not. R. Astr. Soc. 222, 719, 1986)). For Si III λ1533Å(UV2) we generally observe higher values of equivalent widths as calculated for photospheric lines at an adopted Si abundance of N(Si)/N(H) = 3 · 10^{-8} (Fig. 1). The largest values of Si III absorption are found for stars also showing strongest, usually asymmetric Si IV absorption lines (with their asymmetry due to stellar wind).
Photospheric and interstellar components in C\textsc{ii} and S\textsc{ii} resonance lines are separated and discussed, and the spectral type dependence of C\textsc{iii}-UV4 and S\textsc{iii}-UV2 multiplets is investigated.

Stellar wind was studied as indicated in the spectra of Be stars by the presence of extended blue wings in the resonance lines of S\textsc{ii}v-UV1 and C\textsc{iv}-UV1. Our data clearly show the C\textsc{iv} resonance doublet equivalent widths to increase both with increasing $T_{\text{eff}}$ and with increasing $v \sin i$ of the stars. For the equivalent widths of S\textsc{ii}v-UV1 absorption, we find a similar correlation with $T_{\text{eff}}$ but no firm correlation between terminal velocity and stellar latitude (Fig. 2).

Equivalent widths and terminal velocities measured for the S\textsc{ii}v $\lambda 1393 \text{Å}$ (UV1) line were used to determine mass loss rates $\dot{M}$, starting from equation (37) of Dachs and Hanuschik (A&A 138, 140, 1984). Optical depths in the wind flow at wind velocity $V_{\infty}/2$ were derived by fitting observed line profiles to theoretical P Cygni-type profiles calculated by Castor & Lamers (ApJ Suppl. 39, 481, 1979), with resulting values of optical depth $T_{1/2}$ ranging between 0.2 and 0.8. For the ion density fraction, $N_{\text{Siv}} / N_{\text{Si, total}}$, the maximum value of 0.35 obtained in the calculations by Arnaud & Rothenflug (A&A Suppl. 60, 425, 1985) was adopted as a uniform ratio, while the relative Si abundance in the wind, $N_{\text{Si}}/N_{\text{H}}$ was taken to equal $4 \cdot 10^{-5}$.

Resulting mass loss rates derived from S\textsc{ii}v profiles range between $10^{-11}$ and $10^{-9}$ solar masses per year and, on the average, distinctly increase with increasing effective temperature of the star. Evidence for extended blue wings due to stellar winds is also detected in the photospheric components of S\textsc{ii}i $\lambda 1526 \text{Å}$ resonance lines. For several Be stars, time variations of the stellar wind were studied. Spectacular changes were noted in particular for HR 2855 between 1981 and 1987 in the N\textsc{v} and C\textsc{iv} doublet resonance absorption profiles.

![Figure 1](image1.png)

![Figure 2](image2.png)