# OBSERVATIONS OF RADIALLY EXPANDING STRATIFIED ATMOSPHERES OF WOLF-RAYET STARS

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**Abstract.** A correlation between lower excitation potential and radial velocity of violet-displaced absorption components in the spectra of Wolf-Rayet stars is established. The relationship supports the concept of a radially expanding stratified atmosphere in which the expansion velocity increases outwards. The outermost layers of the atmosphere of one star (HD 151932, WN7) display oscillations with a periodicity of about 3.5 days.

The Wolf-Rayet stars differ from normal stars by a number of striking properties. One of them is the appearance of highly broadened emission lines partly accompanied by violet-displaced absorption components.

In 1929, Beals first reported the correlation between ionization potential and half-width of the emission lines. He proposed a spherically symmetric, radially expanding atmosphere. Serious objections against this model (e.g.: different correlations between ionization potential and half-intensity line-width for different elements, the apparently better explanation of the line profiles by a turbulent atmosphere, no detection of the transit-time effect) have been removed by Castor (1970a, 1970b), Castor and Van Blerkom (1970) and Smith and Aller (1971), the latter confirming Beal's correlation. This stimulates the search for a similar relation for the violet-displaced absorption components, especially because, in contrast to the broad rounded emission lines, the absorption components are generally accepted as indicators of an expanding envelope.

Figures 1 and 2 show plots of the expansion velocity of six WC stars vs lower excitation potential of the ions involved. The data are taken from Bappu (1973) (HD 164270, 165763, 192103, 192641 and 193793) and from Seggewiss (1974a) (HD 152270). Despite severe blending problems always arising in WC spectra, most stars display a correlation between expansion velocity and excitation potential. The relationship is clearly defined for HD 165763 (WC5) and HD 192103 (WC8(+OB)). A decreasing lower excitation potential corresponds to an increasing expansion velocity.

Figure 3 shows similar plots for three WN stars. The data for HD 191765 and HD 192163 are again taken from Bappu (1973); the data for HD 151932 are given by Seggewiss (1974b). The radial velocities of possible violet-displaced absorption lines of C IV in these WN stars are omitted. The same relation as for WC stars is noticed. It is extremely well defined for HD 151932 (WN7). The mean radial velocities RV of the He and N ions are listed in Table I together with their laboratory wavelengths $\lambda_{Lab}$ and lower excitation potentials EP. The velocity increases from about $-120$ km s$^{-1}$ for the N V lines (EP = 56.6 eV) to over $-900$ km s$^{-1}$ for He lines (EP = 20 eV).

The explained correlation implies stratification in the envelope of Wolf-Rayet stars since such a variety of different states of ionization and excitation potentials cannot exist simultaneously at one point. Kuhi (1973) has given strong arguments that in

*Sherwood and Plaut (eds.), Variable Stars and Stellar Evolution*, 285–289. 

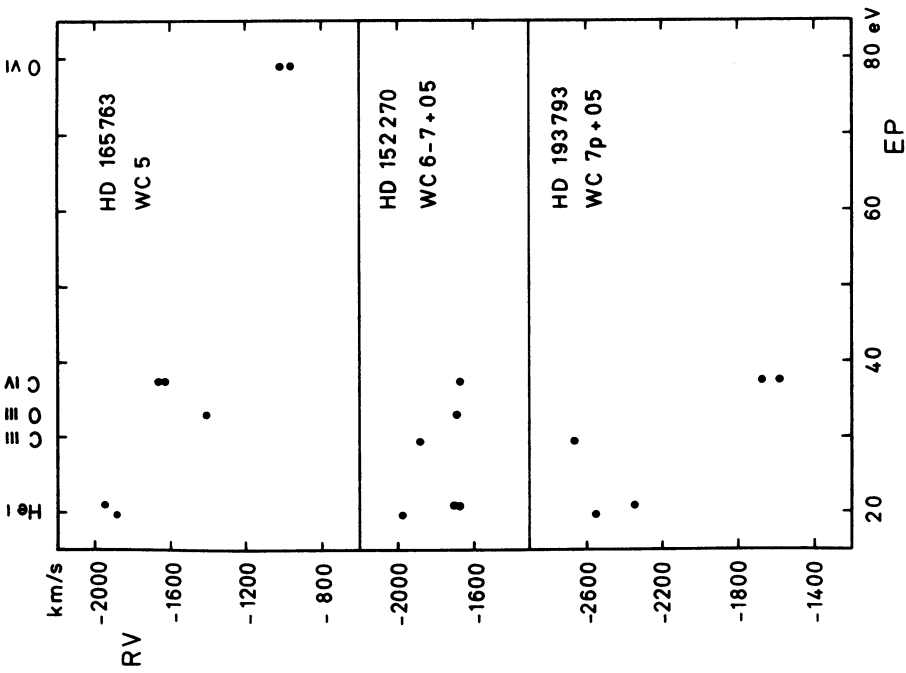


Fig. 1. Correlation of expansion velocity RV of violet-displaced absorption components and lower excitation potential EP. Data for HD 165763 and HD 193793 from Bappu (1973); data for HD 152270 from Seggewiss (1974a).

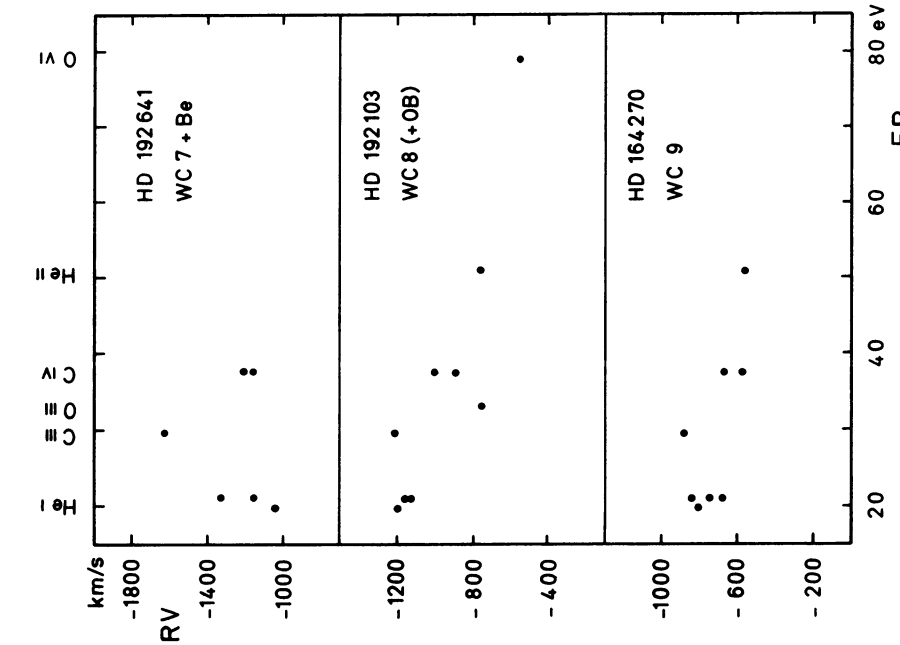


Fig. 2. Correlation of expansion velocity RV of violet-displaced absorption components and lower excitation potential EP from Bappu's data (1973).

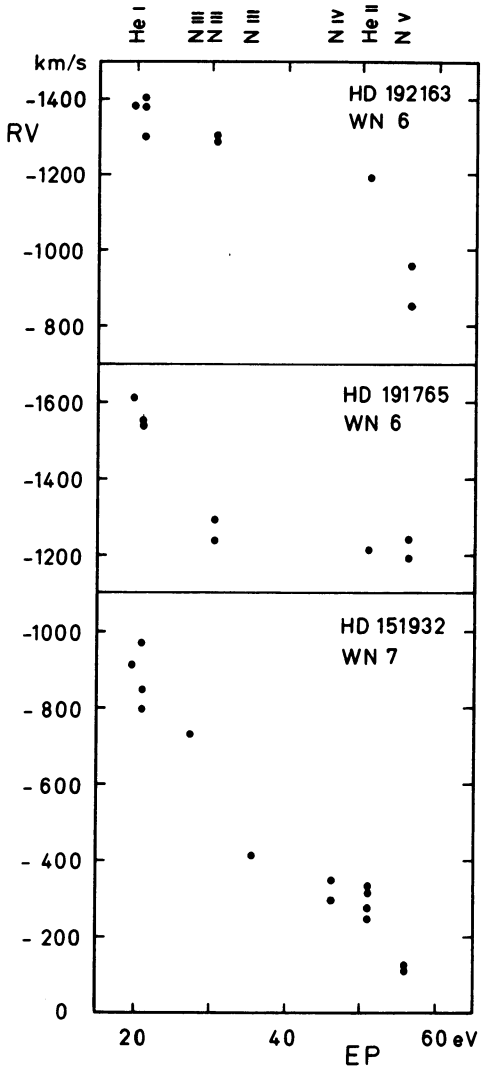


Fig. 3. Correlation of expansion velocity RV of violet-displaced absorption components and lower excitation potential EP. Data for HD 192163 and HD 191765 from Bappu (1973); data for HD 151932 from Seggewiss (1974b).

Wolf-Rayet stars, temperature decreases radially outwards. With our correlation this implies that the velocity field of the atmosphere is an accelerating one, i.e. the expansion velocity increases with increasing radius.

Figure 4 shows a plot of the expansion velocities of different ions in the spectrum of HD 151932 vs observing time (crosses and dots); for comparison the velocity variations of the emission line N IV 4058 Å and the interstellar Ca II lines are given (open circles). The data have been derived from spectrograms taken with the Coudé spectro-

TABLE I

Radial velocities of violet-displaced absorption components in the spectrum of HD 151932 (WN7)

| Ion | $\lambda_{Lab}$ Å | EP eV | RV km s$^{-1}$ |
|---|---|---|---|
| He I | 3889 | 19.7 | −914 |
| | a | 20.9 | −869 |
| He II | b | 50.8 | −276 |
| N III | 4097 | 27.3 | −729 |
| | 3771 | 35.5 | −410 |
| N IV | 3479/84 | 46.8 | −319 |
| N V | 4604/20 | 56.6 | −116 |

(a) 5876, 4471, 3820 Å
(b) 4542, 4339, 4200, 3968, 3923, 3858, 3834 Å

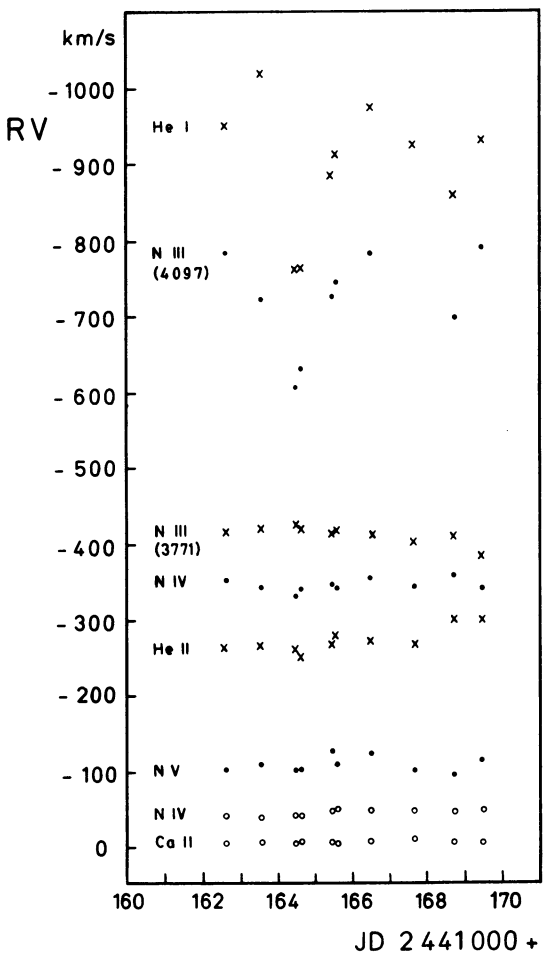


Fig. 4. Radial velocity curves of the violet-displaced absorption components (crosses and dots), the N IV 4058 Å emission line (open circles) and the interstellar Ca II lines (open circles) in the spectrum of HD 151932 (WN7).

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graph of the 152-cm telescope of the European Southern Observatory at La Silla, Chile. The radial velocity curves of the lines with lowest excitation potentials and highest expansion velocities, i.e. He I lines and N III 4097 Å, show a double wave with decreasing amplitude and a periodicity of about 3.5 days. Since these lines are formed at greater distances from the stellar photosphere than the other lines, which indeed do not show variations exceeding the measuring accuracy, the observations give strong evidence for an oscillating outer atmosphere of the WN star HD 151932.

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## DISCUSSION

*M. Friedjung:* Is HD 151932 a binary star?

*W. Seggewiss:* HD 151932 is believed to be a 'single' star. But one should be careful with this statement. I have made statistics on WR stars brighter than $m_v = 10^m.0$. It turns out that 29 of 33 stars or about 88% of the bright WR stars are reported to be binaries.

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