VARIABLE STELLAR WIND FROM THE WN-STAR HD 151932

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Abstract. The effects of the interaction of strong Wolf-Rayet stellar wind with the surrounding interstellar medium in ring-type nebulae are briefly discussed.
The outstanding variability of the envelope of the WN 7 star HD 151932 is explained by small density fluctuations. Variable WR wind may be the reason for the filamentary structure observed in ring-type nebulae.

I. Wolf-Rayet stars in ring nebulae

It is well-known that Wolf-Rayet (WR) stars are closely related to diffuse interstellar nebulae. Approximately 44% of all WR stars are found within H II regions (Crampton, 1971); most stars are responsible for the excitation of the optical nebulae.

Moreover, 9 WR stars (HD 50896, 56925, 89358, 96548, 117688, 147419, 191765, 192163, and MR 97) are the centers of so-called ring nebulae which are distributed around the stars in the form of arcs (Smith, 1973). Excellent photographs and radio contour maps of a typical example (NGC 6888 with HD 192163, WN 6) are given by Wendker et al. (1975).

The results of numerous optical and radioastronomical investigations of the ring nebulae (e.g. Johnson and Hogg, 1965; Smith and Batchelor, 1970; Deharveng and Maucherat, 1974; Wendker et al., 1975; Israel and Felli, 1976) and theoretical interpretations (e.g. Pikel'ner and Shcheglov, 1969; Avedisova, 1972) can be summarized as follows:

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1. The central stars always belong to the nitrogen sequence of the WR stars (spectral types WN 5 to WN 8).

2. All stars are apparently single stars *).
This leads to the assumption that in the process of becoming helium stars the central stars have transferred their outer hydrogen-rich layers by a strong wind to the interstellar medium instead by mass exchange to a close companion.

3. The stellar wind (typical velocity 1000 km/s) "sweeps" up the interstellar gas into an observable shell which is being pushed outwards with a velocity of about 50 km/s (30 km/s for NGC 3199 (HD 89358), 50 to 110 km/s for NGC 6888 (HD 192163), 55 km/s for NGC 2359 (HD 56925); cf. Deharveng and Maucherat, 1974).

4. Ring radii range between 4 pc (NGC 2359) and 18 pc (RCW 104 with HD 147419; cf. Johnson, 1973).

5. Combining model calculations with observed parameters total nebular masses of about 100 $M_\odot$ are derived (cf. Deharveng and Maucherat, 1974; Israel and Felli, 1976).

6. The mass loss rates of the WR stars are between 4 and $10 \cdot 10^{-6}\ M_\odot a^{-1}$. The total masses ejected by the WR stars range between 0.6 and 5 $M_\odot$, depending on the stellar mass loss rates and the dynamical ages of the nebulae.

7. The radio radiation of the nebulae is thermal.

The origin and maintenance of the filamentary structure of the ring nebulae is a problem which has up to now no satisfactory explanation. Smith (1974) concludes that the observed filaments represent variations in thickness of the shells along the line of sight or density fluctuations with constant path length.

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*) No composite spectrum has been observed, no variable velocity detected. Small irregular light variations, though observed, are a common phenomen among WR stars and no sign of binary nature. The binary character of HD 50896 (EZ CMa, WN 5, center of nebula S 308) as quoted by Kuhi (1967) has not been confirmed.

II. The variable envelope of HD 151932

The WN 7 star HD 151932 does not belong to the group of WN stars with ring nebulae. It forms together with about 80 blue giants the association Sco OB 1. The association is surrounded by a nearly complete H II ring (Bok et al. 1955) with the giant dimensions of about $4^{\circ} \times 5^{\circ}$, corresponding to 120 pc x 150 pc. The NE edge of the ring is the bright nebula IC 4628.

In Fig. 1 I have plotted the radial velocity RV of the violet-displaced absorption edges of the emission lines of HD 151932 over the maximum of the lower excitation potential EP and the ionization potential IP of the corresponding ion. This diagram shows the well-known fact that the expansion velocity of the WR envelope increases with decreasing potential or, if we suppose a radiatively driven stratified atmosphere with temperature decreasing outwards, that the envelope is accelerated outwards.

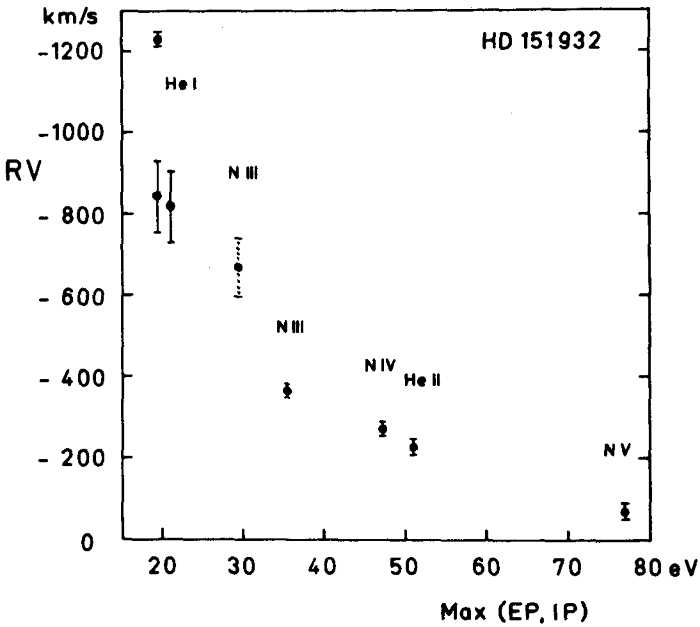

Fig. 1. Expansion velocity of the envelope of HD 151932 (WN 7) vs. maximum of excitation and ionization potential of the corresponding ion.

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It is astonishing that some He I absorption edges around -800 km/s (and probably the heavily blended absorption of N III λ4097) show very large standard deviations compared to "slower" ions and to the fast component of He I λ3889. Fig. 2 gives a close-up of the He I absorption lines (radial velocity RV is plotted versus Julian Date JD; different line strength is indicated by the size of the symbols): The He I λ3889 absorption is split into a constant fast component and a variable one which varies along with the He I λλ4472 and 5876 absorptions in the form of ascending branches separated by about 3.5 days (instead of a wave as suggested by the author in 1974 (Seggewiss, 1974)).

It seems unlikely to me that the variations are induced by an unseen component of the WR star, e.g. by a low-mass star circling around the WR star within the "He I envelope" (second WR phase, cf. de Loore et al., 1975).

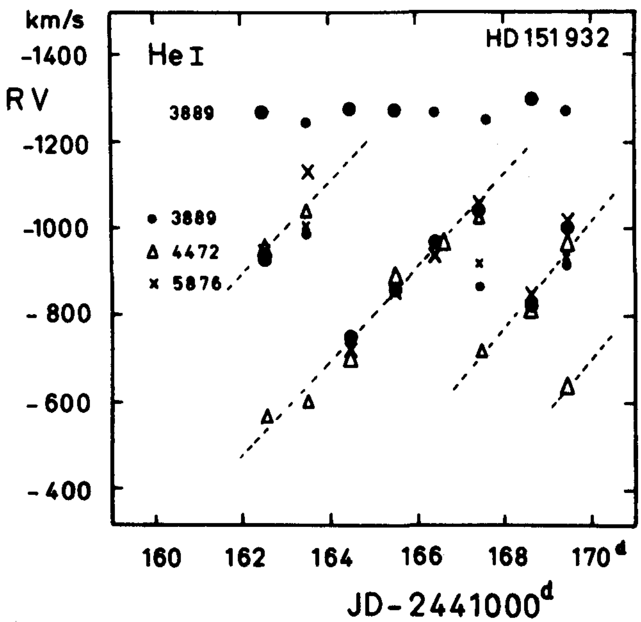

Fig. 2. Radial velocity variations in the "He I envelope", i.e. that layer of the envelope in which He I is excited.

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The variations in the WR envelope may be caused by small changes in the density of the envelope. One can introduce a radius r_o in the envelope which defines the distance of the maximum density of ions and their excited states from the stellar center. Pöllitsch (1975) gives the equation

$$r_o = R\cdot\left(1 - \frac{2n-3}{R\cdot N^2}\cdot\frac{f^*}{f_e}\right)^{\frac{1}{2n-3}} \qquad (n \neq 3/2) \qquad (1)$$

(R stellar radius, N density, $N \sim 1/r^n$).

The functions $f^*(T_{eff})$ and $f_e(T_e)$ have been evaluated up to now only for hydrogen envelopes. Nevertheless, for $N \sim 1/r^2$, equation (1) reduces to

$$r_o = \frac{R}{1 - \frac{const}{N^2}} \quad . \qquad (2)$$

If we now increase the density N by 5%, say, then a radius r_o = 50 R will be reduced to 9 R (80%), but a radius r_o = 1.3 R will be reduced to 1.27 R only (2% reduction). A decrease in density has a similar influence on r_o in the other direction. This means, that small changes of the ion density (whatsoever the origin of those changes may be) affect virtually only the outer parts of the envelope.

Thus the velocity branches of Fig. 2 can be explained by slow declines of density (causing the layer of He I excitation to ascend in the envelope to zones of higher velocity) followed by sudden pseudo-periodically starting clumps of higher density (causing the beginning of a new ascending branch).

The constant component of He I λ3889 may be formed in the outermost layers of the envelope where the metastable lower level is overpopulated by dilution and where the velocity of expansion approaches asymptotically a maximum value.

Variable stellar winds as observed in the case of HD 151932 will affect the structure of the surrounding interstellar medium and may lead to an explanation of the filaments of the ring-type nebulae.

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References.

Avedisova, V.S. 1972, Astron. Zh. 48, 894, Soviet Astron. A.J. 15, 708
Bok, B.J., Bester, M.J., Wade, C.M. 1955, Harvard Reprint No. 416
Crampton, D. 1971, Monthly Notices Roy. Astron. Soc. 153, 303
Deharveng, L., Maucherat, M. 1974, Astron. & Astrophys. 34, 465
Israel, F.P., Felli, M. 1976, Astron. & Astrophys. 50, 47
Johnson, H.M. 1973, in Wolf-Rayet and High Temperature Stars p. 42, Eds. Bappu, M.K.V., Sahade, J., IAU Symp. No. 49
Johnson, H.M., Hogg, D.E. 1965, Astrophys. J. 142, 1033
Kuhi, L.V. 1967, Publ. Astron. Soc. Pacific 79, 57
de Loore, C., de Grève, J.P., de Cuyper, J.P. 1975, Astrophys. Space Sci. 36, 219
Pikel'ner, S.B., Shcheglov, P.V. 1969, Astron. Zh. 45, 953; Soviet Astron. A.J. 12, 757
Pöllitsch, G.F. 1975, Thesis, University München
Seggewiss, W. 1974, Publ. Astron. Soc. Pacific 86, 670
Smith, L.F. 1973, in Wolf-Rayet and High Temperature Stars p. 139, Eds. Bappu, M.K.V., Sahade, J., IAU Symp. No. 49
Smith, L.F. 1974, Proc. Second European Regional Meeting Astron., Mem. Soc. Astron. Italiana, 45, 367
Smith, L.F., Batchelor, R.A. 1970, Australian J. Phys. 23, 203
Wendker, H.J., Smith, L.F., Israel, F.P., Habing, H.J., Dickel, H.R. 1975, Astron. & Astrophys. 42, 173

D I S C U S S I O N of paper by SEGGEWISS:

MIRZOYAN: Are you sure that the WN Star HD 151932 is a single star? The fact is that some of WR stars are spectroscopic binaries and only due to spectral lines the duplicity cannot be proved for many stars of this type, in spite of the fact that statistical studies showed that most of them must be binaries.

SEGGEWISS: Of course, one can never be sure that a star is a single one. Concerning the broad WR lines my experience is that with high-dispersion spectra and modern measuring devices (oscilloscope-type!) the accuracy of radial velocity determinations is comparable to that of "normal" stellar absorption lines.

FRIEDJUNG: Are there any light changes related to the radial velocity changes of the variable He I component? Such changes might be expected if the ejection rate changes.

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SEGGEWISS: Narrow-band photometric observations (band centers at 3635, 4680, 5170 and 5640 Å) carried out by A. Moffat, Montreal, at La Silla, show small light variations in the order of $\pm$ 0^{m}02. They seem to be erratic fluctuations as often observed for WR stars.

WOOD: David R. Florkowski has asked me to make the following remark: HD 193793 is another Wolf-Rayet star with a variable stellar wind. Hackwell et. al. (Ap. J. 210, 137, 1976) have found, over 1970-1975, that the infrared flux from the circumstellar material has decreased by a factor of 6.5. They interpreted this decline to be caused by a decrease in the mass loss rate. Florkowski and Gottesman (MN 177, 105, 1977) have detected radio emission from this star. In October 1975, the radio spectral index, between 8085 and 2695 MHz, was -0.19. They suggested that since the mass flow expands at a finite velocity, the inner regions of the circumstellar shell adjust to a change in the mass loss rate sooner than the outer regions. This lag and the decline in the mass loss rate could account for the observed radio spectral index. Further radio observations were made in March, 1977. The radio flux had declined by at least a factor of 5 since the earlier measurements, and the spectral index was found to be at least +0.6.

Hackwell (private communication) has observed in May 1977, a large increase in the infrared flux. The mass loss rate is now at nearly its 1970 value. Further infrared and radio observations are being planned.

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