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SPECTRAL VARIATIONS OF HD 192163

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RESUMEN

Se tomaron espectros de HD 192163 con una dispersión intermedia (0.7 A canal^{-1}) en el rango espectral 4470-4800 A; se estudian las variaciones de los perfiles y de la velocidad radial. La estrella es variable en ambos sentidos. Se encuentra una velocidad media del sistema $\simeq -100$ km s^{-1}. Las variaciones de los perfiles son parecidas pero no de la misma intensidad que las que se observan en HD 50896 que es una estrella reconocida como binaria. Este análisis indica que HD 192163 también puede ser un sistema binario. Se sugiere la presencia de un objeto colapsado en el sistema.

ABSTRACT

Medium dispersion (0.7 Å channel^{-1}) spectra of HD 192163 in the 4470-4800 Å region are examined for profile and radial velocity variations. The star is variable in both senses. The mean velocity of the system is found to be $\simeq -100$ km s^{-1}. The profile variations are similar, but not so strong as those in HD 50896 which is known to be a binary. This analysis supports the idea that HD 192163 may be a binary system. The presence of a collapsed companion is suggested.

Key words: STARS-BINARIES – STARS-WOLF-RAYET.

I. INTRODUCTION

HD 192163 is classified as a single WN6 star by Smith (1968) and is frequently described as the prototype of this subclass (Castor and Van Blerkom 1970). It is associated with the "ring" nebula NGC 6888 which has been extensively studied (Johnson 1973; and references therein). Johnson (1973) remarks that the mean velocity of the nebula may be appropriate to a "runaway" O star. Because there is reason to suspect that the WN stars associated with "ring" nebulae may be also associated with collapsed companions (Van den Heuvel 1976; Firmani *et al.* 1979), a careful radial velocity (RV) variation study of HD 192163 may render significant results.

II. OBSERVATIONS

The observations were carried out between October 31 and November 8, 1977 with the 40-inch telescope of the Observatorio Astronómico Nacional in Tonantzintla, Puebla (México), using a low dispersion spectrograph and a SIT Television Camera which has been adapted for astronomical purposes (Ruiz 1974; Solar 1977). The spectral range covered is λλ4460-4810 with a dispersion of 0.7 Å channel^{-1} over the 500 channels. The exposure time was chosen so as to have a signal to noise ratio of about 300 at the He IIe 4686 line. The He-Ar comparison spectra are used to calibrate the channels into wavelengths. The stability of the optoelectronic system is better than 0.1 Å.

Profile variations contain information as to the variability of a star. This method of detecting variability is particularly powerful in our case due to the high signal to noise ratio of the SIT spectra. A calibration of the intensity scale would be highly desirable. However, the observing conditions were not adequate for an absolute calibration, which limits us to a relative one. The intensity scale calibration was carried out by interpolating a polynomial to a continuum which is defined for the intervals λλ4470-4500, 4576-4580 and 4770-4800, and measuring intensities with respect to this continuum.

Table 1 contains the information regarding the observations of HD 192163. Columns 1 and 2 give the number of the observation and the Julian Day of the observation respectively. The remaining columns will be explained further ahead.

a) *Profile Variations*

Profile variations in HD 192163 are by far much less marked than those which occur in HD 50896 (Firmani *et al.* 1979; Koenigsberger 1978). However, changes in the uppermost parts of He IIe 4686, N IIIe 4634-42 and He IIe 4542 are present. The variations in the uppermost part of He IIe 4686 occur as changes from a rounded profile with a red shoulder (spectra S788, S790, S807, S809) to one which appears to have a redward-displaced absorption (S707, S709), passing through a symmetric profile which has a sharp peak (S697, S730, S732).

The configuration of the violet absorption of He II 4542 undergoes changes from a sharp absorption (S707, S709, S763) to a shallower one. The principal variations of the emission at λ4542 is the occasional appearance of a superposed, sharp absorption which cuts into the underlying emission and is centered approximately at 4545 Å(S763). Also, the uppermost part of N III 4634-42 is affected by various absorptions which vary in intensity.

It is very difficult to establish a periodicity of the profile variations in HD 192163 on the basis of only 10 spectra spread over 6 nights. However, due to the similarity of these spectral variations with those of HD 50896 it seems reasonable to fit a period to the observations as a first approach to the problem of the binary nature of this star. On the basis of the comparison of these spectral variations a period of 4.5 days is deduced, and the phase 0.5 (WR, behind) at J.D. 2443447.54 is suggested. The phase obtained for each observation is listed in column 3 of Table 1.

Figure 1 shows the profile variations in HD 192163. Here we have reproduced, in order of increasing phase, one spectrum from each different night. Notice that the vertical scale for the He IIe 4686 line is not the same as that for the other features.

b) *Radial Velocity Variations*

The normalized spectra were measured for radial velocity variations. The center of the He IIe 4686 line was measured at four different levels above the continuum (3,4,4.5,5). The average of these measurements is in column 4 of Table 1.

The centers of the features He IIe 4542, N IIIe 4634-42, He IIa 4542, N Va 4604, and 4620 were measured three separate times due to the complicated nature of the profiles and the manner in which these vary. The center was taken to be that point which lies at the same distance from either wing at half intensity of the feature. The averages of these measurements are found in columns 5 to 9 of Table 1.

Table 2 summarizes the results of the RV variations measurements. Columns 1 and 2 give the feature and its principal identification. The average RV and the full amplitude of the variations in km s^{-1} can be found in columns 3 and 4, respectively. Columns 5 and 6 give the phase of maximum and minimum radial velocity.

Several things can be pointed with relation to this table. First and perhaps most important is the result that the emission lines He II 4542 and N III 4634-42 have negative mean velocities of approximately the same value (~ -110 km s^{-1}) while He II 4686 has a positive velocity ($\sim +100$ km s^{-1}). This "red-shift" of the He II 4686 line is a well-known phenomenon in Wolf-Rayet stars and some Of stars (cf. 29 UW CMa, Struve and Sherman 1941; γ^2 Vel, Ganesh and Bappu 1967) and may be the

TABLE 1

MEASURED RADIAL VELOCITY FOR EACH FEATURE (km s^{-1})

#SIT	JD(-2443000)	Phase	He IIe 4592	He IIe 4686	N IIIe 4634-42*	He IIa 4542	N Va 4604	N Va 4620
697	447.540	.50	−110	80	−133	−1178	−1151	−947
707	448.628	.74	−110	101	−140	−1099	−1108	−929
709	448.653	.75	−103	97	−127	−1150	−1075	−897
730	452.623	.63	−151	99	−133	−1112	−1148	−947
732	452.688	.64	−113	110	−121	−1053	−1112	−892
763	453.695	.87	−124	129	−116	−1236	−1135	−975
788	454.653	.08	−110	105	−113	−1343	−1204	−959
790	454.670	.08	−112	125	−100	−1343	−1146	−949
807	455.656	.30	−104	121	−137	−1188	−1131	−936
809	455.672	.31	− 99	105	−121	−1111	−1103	−914

* Zero-velocity wavelength used: λ_0 (N III 4634-42) = 4638 Å.

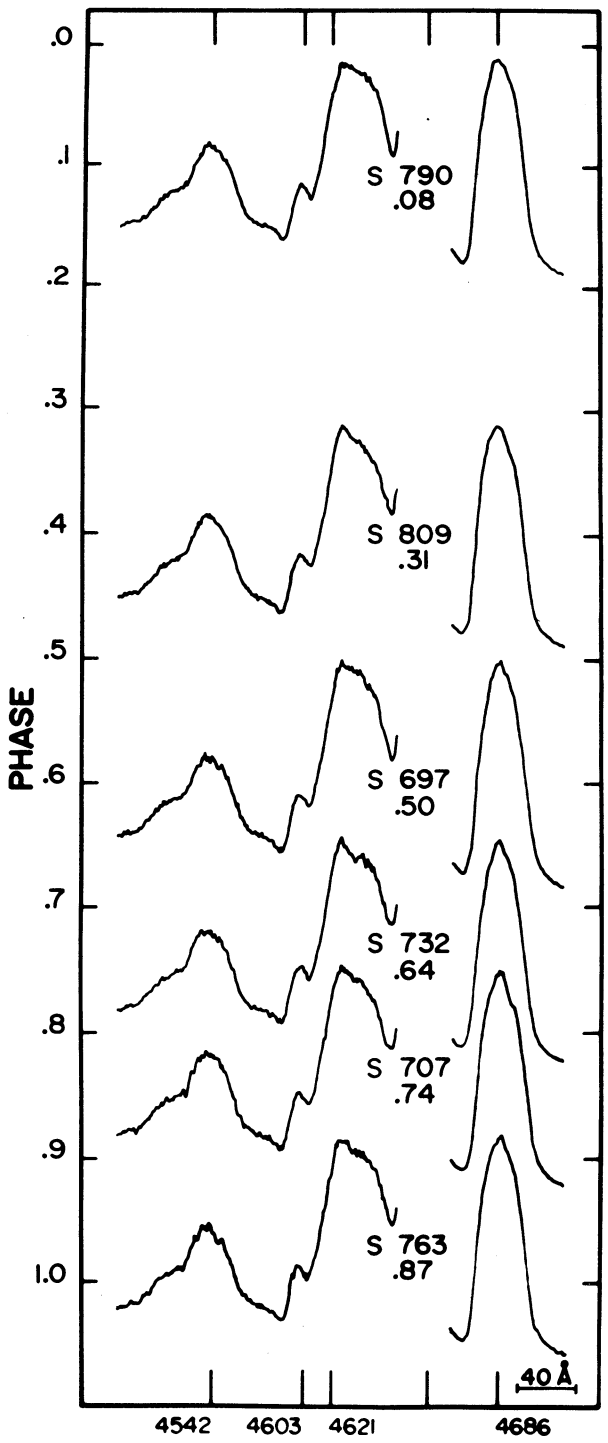

Fig. 1. Profiles of the principal spectral features in HD 192163 sorted with phase. Each spectrum is labelled with its SIT number and the phase obtained using P = 4.5 days. The vertical scale of the He IIe 4686 profile is smaller than that of the other features.

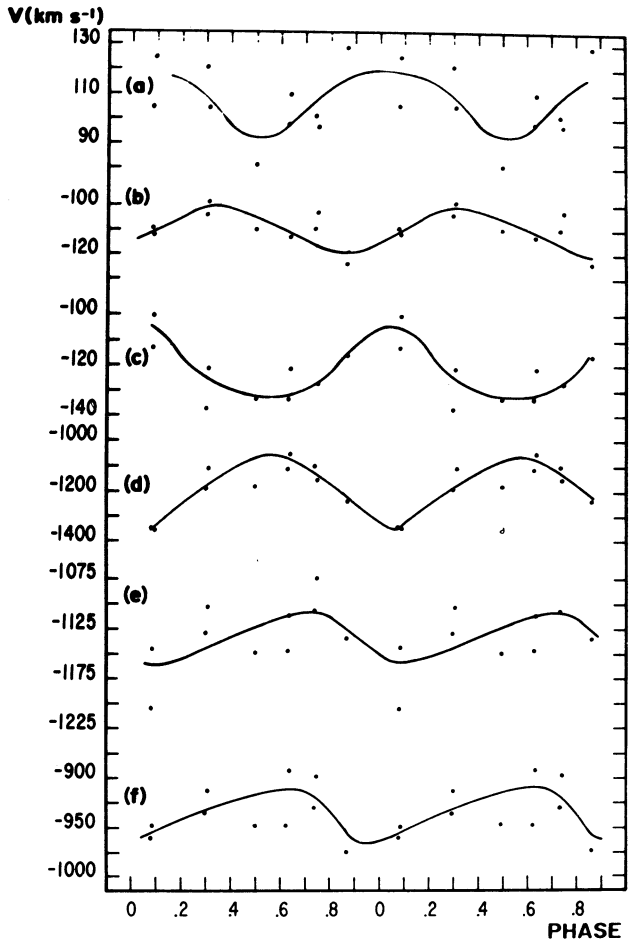

Fig. 2. Radial velocity variations folded with a 4.5 day period of a) He IIe 4686, b) He IIe 4542, c) N IIIe 4634-42, d) He IIa 4542, e) N Va 4604 and f) N Va 4621.

result of electron scattering by free electrons (Auer and Van Blerkom 1972). It is somewhat surprising that this redshift phenomenon would affect only He II 4686; perhaps the answer to this may be related to the intensity of this line.

Second, the mean velocity of the two N V violet absorptions differs by about 200 km s^{-1} while their RV variation amplitudes are identical. The discrepancy is probably related to the fact that N Va 4620 cuts into the N Ve 4604, added to the proximity of N IIIe 4634-42.

Third, the amplitude of the He IIa 4542 variations is 5 to 20 times greater than that of the other features. This is probably the result of the severe blending with N IIIe 4514-30 and the variations which the blue wing of He IIe 4542 undergoes.

If we plot the data in columns 4 to 9 of Table 1 on a RV-phase diagram, we obtain Figures 2a to 2f. The

TABLE 2

SUMMARY OF THE RV VARIATIONS IN HD 192163

Feature	Identification	Average RV (km s^{-1})	Amplitude of RV variations (km s^{-1})	Phase of max. RV	Phase of min. RV
He IIe 4686	He II 4685.7	104	35	~ 0.5	~ 0.0
He IIe 4542	He II 4541.6	− 109	15	~ 0.85	~ 0.35
N IIIe 4634-42	N III 4634-4641.9	− 120	30	~ 0.5	~ 0.0
He IIa 4542	He II 4541.6 N III 4530-4535.1 N III 4546.4	−1210	300	~ 0.1	~ 0.6
N Va 4604	N V 4603.7	−1132	63	~ 0.1	~ 0.7
N Va 4620	N V 4620 N III 4634-4641.9:	− 944	62	~ 0.1	~ 0.7

curves are eye-drawn estimates. These RV curves are not in contradiction with the periodicity suggested by the profile variations. It is interesting, though, that the maxima or minima of all curves, except the one for He IIe 4542, occur at either phases around 0 or 0.5. The He IIe 4542 curve seems to have its extreme values at phases 0.35 out of phase with the rest.

III. DISCUSSION

HD 192163 is one of the WR stars surrounded by a ring nebula (NGC 6888). The evolutionary stage of these objects has been interpreted by Van den Heuvel (1976) as the second WR phase during the evolution of the massive binary stars. In terms of this picture these WR stars have to be objects associated with a collapsed companion. However, due to the lack of observational evidence in favor of the binary nature of these stars they have been usually considered to be single objects. Only recently Firmani *et al.* (1979) and Koenigsberger (1978) demonstrated that the spectrum of HD 50896 (associated with the nebula S308) is variable with a period of 3.7 days and that the star is very probably a binary. This conclusion has been confirmed by more spectrophotometric data by Firmani *et al.* (1980) and polarimetric observations of McLean (1979). The results of the previous section have to be interpreted in this context.

The average RV of HD 192163 obtained from He IIe 4542 and N IIIe 4634-42 confirm the results of Lozinskaya and Episov (1968) that HD 192163 has a radial velocity of about −100 km s^{-1}. This velocity is peculiar, and as Johnson (1973) points out, appropriate to a "runaway" O star. We therefore have evidence which points to a supernova event having occurred in HD 192163, which means that it may be accompanied by a collapsed companion.

The profiles of the lines are variable and the centers vary in wavelength. These spectral variations are similar to those found in HD 50896 and this is an ulterior, more direct, evidence in favor of the binary nature of this star. Due to the small number of spectra, the periodicity obtained from our data must be taken as tentative and future observations should be made. If the periodicity of the spectral variation is confirmed, then HD 192163 will be the second example of a binary WR star surrounded by a ring nebula. In this case, the evolutionary interpretation mentioned before for these objects will be strengthened.

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