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On the polarimetric studies of the multiple system HD 211853 including a Wolf-Rayet star

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Abstract. The results of short-term observations of HD 211853 conducted at SAO RAS in 1999 September are compared with those of earlier investigations of the system by St.-Louis et al. (1988) and Polyakova (1993). The amplitude of linear polarization variation of the system which is caused by the scatter of light of the O component in the WR star's envelope in the main (WN6+O) pair increased from 0.2–0.3 % to 1 % in our observations.
Analysis of the results of the first two polarimetric studies of the system yielded different values of the orbit inclination of the (WN6+O) pair: $i_{polar} = 78.2°$ in St.-Louis et al. (1988) and $i_{polar} = 65°$ in Polyakova (1993). The crude failure to comply with the criterion $\Delta\Omega = |\Omega_1 - \Omega_2| = 90°$ that we revealed in the two analysis causes doubt in either estimate of i_{polar}. A co-operative examination of three series of polarization observations of HD 211853 allows an assumption to be made that the first two curves of linear polarization variations of the system with the phase of the orbital period $P = 6\overset{d}{.}6884$ (observations of 1984–1986 and 1989) displayed an excited state of the (WN6+O) pair preceding the expulsion of the outermost parts of the WR envelope. The latter is evidenced by a sharp drop in linear polarization of the system (to the level of polarization of the interstellar medium in its neighbourhood), noted in our 1999 observations, at phases close to the second conjunction in the (WN6+O) pair (the O star is at the front).
Basing on the fact that HD 211853 is a member of the association Cep OB1, an attempt is made to determine the most likely values of physical parameters of the stars of the (WN6+O) pair. From our estimates the spectrum of O star is close to O7V, $m_O \approx 25 m_\odot$, $m_{WN} = 8 - 12 m_\odot$, $a_{WR} + a_O = 47 - 50 R_\odot$ and $i = 65° - 75°$.

Key words: stars: Wolf-Rayet — stars: polarization: individual: HD 211853

1. Introduction

HD 211853 (MR 116, GP Cep) is a multiple star consisting of two pairs of close binary systems, one of which includes a WR component of the nitrogen sequence (WN6). Wilson (1940) was the first to notice the O absorption lines in the spectrum of HD 211853. He referred them to a companion of the WN6 star. Hiltner (1945) confirmed Wilson's assumption on the duplicity of the star, having found from a radial velocity curve, derived from measurements of emission lines, an orbital solution with a period of $6\overset{d}{.}6864$. However, the great scatter on the V_r curve, obtained from measurement results of O absorptions, did not allow him to reliably define the physical parameters of the system. Having confirmed the radial velocity variations, Bracher (1968) proposed to revise the orbital period value to $6\overset{d}{.}6881$.

In early photometric investigations of the system carried out by Hjellming and Hiltner (1963), Stepien (1970) and Cherepashchuk (1975) a light variability of HD 211853 with a period of $6\overset{d}{.}6864$ was found. The light curve showed a shallow minimum ($\Delta m \approx 0\overset{m}{.}1$) at phases close to the conjunction, in which the WR star was at the front, and a large scatter of light estimates at all remaining phases. Cherepashchuk (1975) explained these features of the light curve by the fact that atmospheric obscuration of the O star by the WR component's envelope took place.

Massey (1981) concluded in his spectroscopic studies of HD 211853 that the revision of the main period to $6\overset{d}{.}6884$ and introduction of an additional period of $3\overset{d}{.}4698$ explained all the anomalies in the behaviour of the system light and in that of radial velocities obtained from measuring of O absorptions. In his opinion, the system consists of two pairs of close binaries:

WN6+O (pair "A"; $P_{\text{“A”}} = 6\overset{d}{.}6884$) and

O+O (pair "B"; $P_{\text{“B”}} = 3\overset{d}{.}4698$).

The three above mentioned series of early photometric investigations and the later photometric studies of Moffat and Shara (1986), Annuk and Hugis (1982) confirmed the reality of existence of a second period, having detected eclipses in both pairs. In pair "B" two eclipses are observed, in pair "A" only one eclipse is noted by the majority of researchers. A very shallow eclipse ($\Delta m \approx 0^m.05$) found by Annuk (1994) on the light curve of the system plotted with $P = 6^d.6884$, at phases close to $0^p.5$ remains not confirmed yet.

The assumption of Panov and Seggewiss (1990) that the WR component is also contained in pair "B" is not confirmed either by the spectroscopic investigation of Massey (1981) or by the polarimetric studies of St.-Louis et al. (1988) and Polyakova (1993). One more assumption of these authors that there exists a third period of $2^d.34607$ is not confirmed by the photometric studies of Annuk (1994).

In spite of the fact that a general understanding of the system has presently been achieved, the failure to separate absorptions of the O star of pair "A" from the absorptions of the O stars of pair "B" superimposing on them does not yet permit obtaining accurate physical parameters of the stars of the system.

Massey (1981), using 1) the mass function that he obtained for the stars of pair "A" from the radial velocity curve constructed from emissions, 2) the fact of the presence of eclipse in pair "A", and 3) the relationships between the lights of stars of the multiple system which he derived from the analysis of the HD 211853 spectra, imposed constraints on the mass of the WR star: $m_{WR} = 10 - 25m_{\odot}$ at $m_O \approx 30m_{\odot}$. Massey (1981) pictured further refinement of physical parameters of the stars of the system as obtaining spectra of HD 211853 with a higher resolution and signal-to-noise ratio needed for separation of absorptional O blends. The refinement of physical parameters of the stars of pair "A" could also be facilitated by deriving more accurate values for the inclination of its orbit from polarimetric studies of the system.

The very first measurements of linear polarization of HD 211853 were made by St.-Louis et al. (1988) with the polarimeter "MINIPOL" at the telescopes of Arizona University in 1984–1986. Later on, Polyakova (1993) reported the results of her polarimetric observations of the system made in 1989 with the AZT–14 telescope of the Byurakan observing station of Leningrad University. In both studies two-wave curves of polarization variations with the orbital period phase of pair "A" (P=$6^d.6884$) were derived. An attempt to convolve the results of the observations with the additional period $P_{\text{"B"}} = 3^d.4698$ did not reveal appreciable modulation. The latter was used by Polyakova (1993) for negation of the assumption by Panov and Seggewiss (1990) that pair "B" also contains a WR star. Analysis of the results of the first two polarimetric investigations of the system yielded different values of inclination of the orbit (WN6+O) pair: $i_{polar} = 78.2°$ in St.-Louis et al. (1988) and $i_{polar} = 65°$ in Polyakova (1993).

2. Results of polarizational observations of HD 211853 in 1999 September

By including HD 211853 in our programme of polarizational observations, we wanted first of all to solve the problem of the most reliable estimate of the orbit inclination of the main (WN6+O) pair. The observations, unfortunately very short, were conducted with the telescope Zeiss-1000 of SAO RAS in 1999 September. A two-channel polarimeter "MINIPOL" of Arizona University (Frecker and Serkowski, 1976) placed at the Cassegrain focus of the telescope was employed. Quasisimultaneous measurements of the u and q Stokes parameters were made in the B band. To obtain the parameters with an accuracy of 0.05 %–0.07 %, 6–7-minute exposures were required. A standard star with zero polarization (HD 212311) was observed to determine the instrumental polarization. To define the zero point shift of our system of counting position angles, standard stars with known polarization of radiation (HD 204827 and HD 218342) were observed. Before and after the observations of each of the stars, polarization of the sky background was measured.

Primarily, all the obtained data were corrected for the contribution of the sky background polarization. Then, the observations of HD 211853 and of the standard stars were cleaned of the instrumental polarization. After that, using the polarization standard stars the shift of the zero point of our system of counting position angles was found, and the Stokes parameters u and q were transferred to the equatorial coordinate system. Table 1 contains the final results of our polarimetric observations of HD 211853. In the first column of the table are listed the Julian dates of the observations reduced to the centre of the Sun, the second one presents the phases expressed in fractions of the orbital period of pair "A". The phases were computed by the formula $T_{min1} = 2443690^d.32 + 6^d.6884 \cdot E$ taken from the paper by Massey (1981). The third–sixth columns of Table 1 give the normalized Stokes parameters ($u = U/I$ and $q = Q/I$) in the equatorial coordinate system, the degree of linear polarization of radiation of the system $P = (u^2 + q^2)^{1/2}$ and the position angle of the polarization plane Θ ($tg2\Theta = u/q$). To illustrate the accuracy and stability of observations, in Table 2 are compared the mean estimates of the polarization standards obtained in 1999 with their catalogue values. The results of our polarization measurements are presented also in Fig. 1 by filled circles. The same figure displays the observational data of

Table 1: *The log of polarization observations of HD 211853 made by us in September 1999*

J.D.⊙ (2400000+)	Φ in frac. of P	q(%)	u(%)	P(%)	Θ°
51437.438	0.292	-0.783	2.884	2.988	52.6
51437.536	0.306	-0.788	2.841	2.948	52.7
51439.262	0.564	-0.945	2.827	2.981	54.2
51439.268	0.565	-0.839	2.804	2.927	53.3
51439.374	0.581	-0.769	2.822	2.925	52.6
51439.380	0.582	-0.807	2.799	2.913	53.0
51439.409	0.586	-0.707	2.931	3.015	51.8
51439.518	0.603	-0.667	2.882	2.958	51.5
51440.484	0.747	-0.161	4.013	4.016	46.1
51440.491	0.748	-0.100	4.010	4.011	45.7
51440.550	0.757	-0.101	4.089	4.090	45.7
51440.559	0.758	-0.075	4.015	4.016	45.5
51441.344	0.876	-0.006	3.911	3.911	45.0
51441.380	0.881	+0.100	3.922	3.923	44.3
51441.389	0.882	-0.107	3.989	3.990	45.8
51441.464	0.894	-0.062	3.743	3.744	45.5
51441.473	0.895	+0.084	3.844	3.845	44.4
51441.537	0.904	+0.012	3.883	3.883	44.9
51441.544	0.906	+0.056	3.811	3.811	44.6

Table 2: *The comparison of the mean estimates of P obtained for polarization standards in the 1999 September observations with their catalogue values*

Standards of polarization	HD 204827	HD 218342
$\bar{P}_{B\ 1999}$	5.59% ± 0.03%	1.90% ± 0.05%
$P_{B\ catalog.}$	5.56% (Serkowski et al., 1969)	1.87% (Coyne and Gehrels, 1966)

St.-Louis et al. (1988) and Polyakova (1993) (open circles and open triangles, respectively). It is seen from Fig. 1 that the results of the three series of polarimetric observations are in poor agreement with each other. The greatest discrepancy, however, is seen at phases $0\overset{p}{.}3 - 0\overset{p}{.}7$, when the O component of pair "A" is located at the front of the WR star. Our estimates of polarization of the system at phases $\approx 0\overset{p}{.}3$ and $0\overset{p}{.}6$ proved to be much lower than the results of observations obtained in the two previous studies. Moreover, they turned out to be considerably lower than the level of polarization of the interstellar medium in the vicinity of the system ($P_I = 3.73$ % from the estimate made by St.-Louis et al. (1988) and $P_I = 3.91$ % from Polyakova's (1993) evaluation) which must not happen. In order to show the correctness of our 1999 observational results once again, we decided, in addition to the data of Table 2, to present the results of polarization observations of another WR binary, V 444 Cyg, which has shown a fairly stable curve of linear polarization variation with phase of the orbital period for over three decades. The observations of V 444 Cyg were carried out on the same nights either immediately before observations of HD 211853 or directly after them. These data are given in Appendix in the table and in the figure that follows it, where the results of our observations of V 444 Cyg are compared with the results obtained by Robert et al. (1990). We consider a fairly good agreement between the results of these two series of observations of V 444 Cyg as an additional confirmation of the stability of functioning of our equipment and photometric sky quality in our observations of 1999 September.

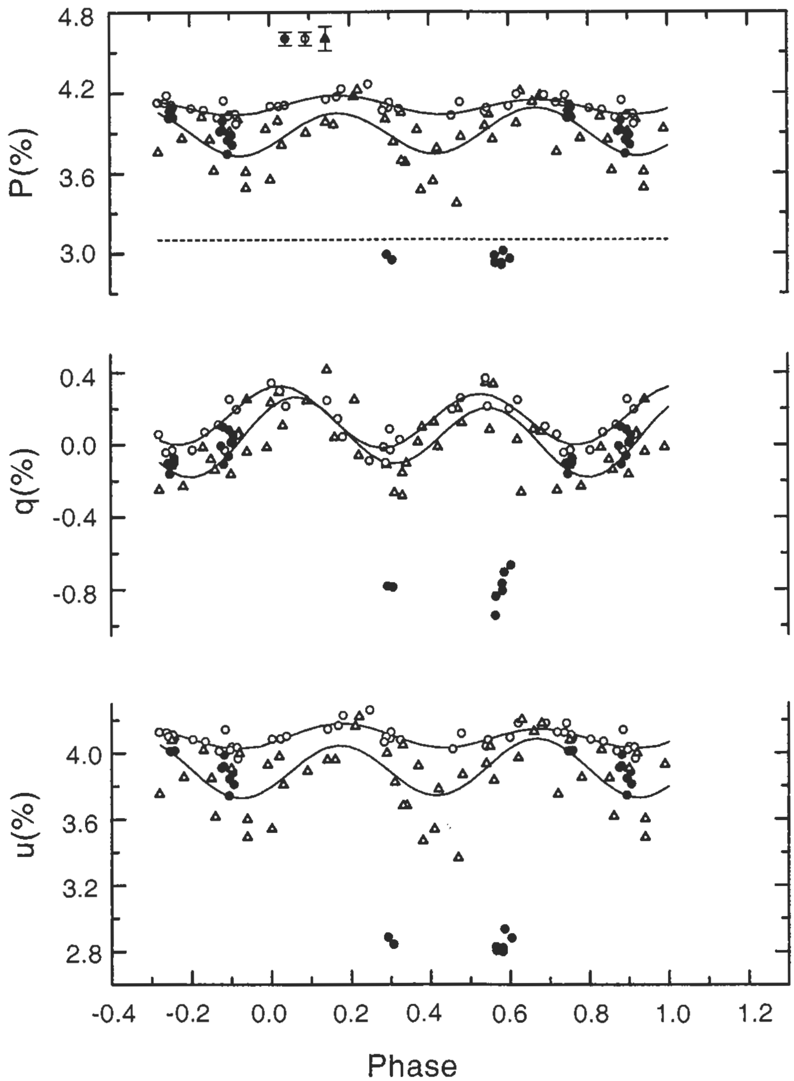

Figure 1: *The curves of variation of linear polarization (P), Stokes q and u parameters with phase of the orbital period ($P_{\text{"}A\text{"}}$ = 6ᵈ6884) plotted for HD 211853 from the results of our observations of 1999 September (filled circles). The open circles and triangles represent the results of St.-Louis et al. (1988) (observations of 1984–1986) and Polyakova (1993) (1989 observations), respectively. The solid line is the theoretical representation of the curves. The estimate of polarization of the interstellar medium in the neighbourhood of HD 211853 is plotted by the dashed line.*

3. Investigation of linear polarization of the interstellar medium around HD 211853

The sharp drop of polarization of the system at phases ≈ 0ᴾ3 and 0ᴾ6 noted in our observations made us critically review the estimate of polarization of the interstellar medium in the neighbourhood of the system. The interstellar polarization in the direction of HD 211853 was determined by us by means of investigation of polarizing capacity of the interstellar matter (P/A_V) in its vicinity. The procedure well described by Polyakova (1974; 1976) and Abramian (1982) was used. The data on 27 neighbouring stars (P, Θ, E_{B-V}

and $(m_0 - M_V)$) in a circle of radius 2° were borrowed from the catalogue of Hiltner (1956). The interstellar extinction for these stars was determined with the aid of the standard law of extinction $A_V = 3.1 \cdot E_{B-V}$. Since the system under study contains the WR component, then, as in the case of single stars with envelopes (Polyakova, 1974; 1976), the extinction A_V found for the system from colour excess includes not only the interstellar extinction but also the absorption in the envelope. For this reason, the interstellar extinction in the direction of HD 211853 was determined by us from the relation $A_V - (m_0 - M_V)$ plotted from the 27 neighbouring stars and approximated by the formula:

$$A_V = -9.5521+2.2481(m_0-M_V)-0.1060(m_0-M_V)^2.$$

Using the distance modulus $(m_0 - M_V) = 12^m\!.7$, following from the membership of HD 211853 in the association Cep OB1 (this question will be discussed in more detail below), we obtained an estimate of the interstellar extinction of the medium in the direction of HD 211853, $A_V = 1^m\!.9 \pm 0^m\!.1$, which is by $0^m\!.6$ less than the value of A_V obtained from colour excess, which is given for the system in the catalogue of Van der Hucht et al. (1988), ($E_{b-v} = 0^m\!.67 \rightarrow E_{B-V} = 0^m\!.81 \rightarrow A_V = 2^m\!.5$). Then, using the neighbouring stars, the relations between polarizing capacity of the interstellar matter (q/A_V and u/A_V) and the interstellar extinction (A_V) were plotted. The least-squares method yielded the following theoretical approximations for these relations:

$$q/A_V = -0.6061 + 0.1795A_V,$$
$$u/A_V = 1.9108 - 0.1585A_V.$$

Using these formulae for HD 211853 (at $A_V = 1^m\!.9$) the following parameters of interstellar polarization in the vicinity of the system were derived:

$$q_I = -0.50\% \pm 0.13\%, u_I = 3.06\% \pm 0.27\%,$$

$$P_I = 3.10\% \pm 0.29\%.$$

It is exactly this estimate of interstellar medium polarization in the neighbourhood of HD 211853 is plotted by the dashed line in the upper part of Fig. 1. With allowance made for the interstellar polarization determination errors, we can state that in the 1999 observations, at phases close to the second conjunction in the (WR+O) pair (the O star is at the front), the linear polarization of the system fell to the level of interstellar medium polarization in its vicinity.

4. Analysis of the results of polarimetric exploration of HD 211853

Our observations are scanty and no Fourier analysis of them is possible. To understand which of i_{polar} is the most likely, we decided to compare the results of analysis of the polarimetric observations of St.-Louis et al. (1988) and Polyakova (1993). We had to perform a repeated interpretation of the results of the Fourier analysis for the observations of St.-Louis et al. (1988) because not all the parameters of interest to us were presented in their paper. As to the polarimetric observations of Polyakova (1993), we had to repeat the Fourier analysis of the results of observations because her paper presented only the coefficients at the first harmonics of expansion. The results of our analysis of Polyakova's observations are given in Table 3. As usual, to connect the coefficients of the Fourier expansion with geometrical and physical parameters of the system, the model of Brown et al. (1978) was used. The results of analysis of the polarimetric observations of St.-Louis et al. (1988) and those of Polyakova (1993) are compared in Table 4. The first line of Table 4 gives the orbit inclination value for the (WN6+O) pair obtained from the analysis of the second harmonics of expansion. In the second and third lines are presented the values of the angle Ω, which characterizes the orientation of orbit of the (WN6+O) pair in space obtained from the analysis of the first (Ω_1) and second (Ω_2) harmonics. The fourth line shows the absolute values of the difference in these values. In the six lines that follow are collected the values of some spatial integrals ($\tau_0\gamma_3, \tau_0\gamma_4$) and their combinations ($\tau_0 G = \tau_0(\gamma_1{}^2 + \gamma_2{}^2)^{1/2}$, $\tau_0 H = \tau_0(\gamma_3{}^2 + \gamma_4{}^2)^{1/2}, H/G, \gamma_4/\gamma_3$), which characterize the features of the distribution of matter in the scattering WR envelope. Five of them were calculated in an analytical way (see the formulae in the paper by Drissen et al. (1986)), the value of $\tau_0 G$ was derived graphically (Brown et al., 1978). The last but one line of Table 4 gives the differences $\Delta u'$ between the u'_c coordinate of the centre of the ellipse described by the second harmonics and the u'_I (u parameter of interstellar polarization). According to the theory of Brown et al. (1978), these two values must be equal ($u'_c = u'_I$) in the coordinate system q', u' related to the binary system. The fulfilment (or nonfulfilment) of the latter allows one to judge of the absence (or presence) in linear polarization of a constant component associated with the system itself. We used the estimate of interstellar polarization that we obtained above ($q_I = -0.50\%$ and $u_I = 3.06\%$). In the $q'u'$ coordinate system related to the star, these parameters assume the values:

$$q'_I = 0.97\%, u'_I = -2.95\%$$

in the analysis of observations of St.-Louis et al. (1988),

$$q'_I = -0.66\%, u'_I = -3.03\%$$

in the analysis of observations of Polyakova (1993).

Table 3: *The coefficient of expansion into the Fourier series of the Stokes q and u parameters obtained by us when analysing the observations of Polyakova (1993)*

q_0	q_1	q_2	q_3	q_4	u_0	u_1	u_2	u_3	u_4
0.0464	0.0165	0.0453	0.1458	0.1184	3.9009	-0.0152	-0.0151	-0.0890	0.1402

Table 4: *The comparison of geometrical and physical parameters obtained by us from the analysis of the polarimetric observations of HD 211853 carried out by St.-Louis et al. (1988) and Polyakova (1993)*

	St.-Louis et al. (1988) (observ.1984-86)	Polyakova (1993) (observ.1989)
$i_2°$	78.2	56.8
$\Omega_1°$	11.9	157.5
$\Omega_2°$	171.1	201.6
$\Delta\Omega° = \|\Omega_1 - \Omega_2\|$	159.2	44.1
$\tau_0\gamma_3$	1.47×10^{-3}	0.79×10^3
$\tau_0\gamma_4$	-0.36×10^{-3}	-1.24×10^3
$\tau_0 G$	0.16×10^{-3}	0.26×10^{-3}
$\tau_0 H$	1.52×10^{-3}	1.47×10^{-3}
H/G	9.5	5.7
γ_4/γ_3	-0.245	-1.574
$\Delta u'$	-11.2×10^{-3}	-5.8×10^3
A_p	1.58×10^{-3}	1.92×10^3

The coordinates of the centre of the ellipse described by the second harmonics of expansion in the same coordinate system, $q'u'$, are:

$$q'_c = 0.49\%, u'_c = -4.07\%$$

in the analysis of observations of St.-Louis et al. (1988),

$$q'_c = -1.48\%, u'_c = -3.61\%$$

in the analysis of observations of Polyakova (1993).

The last column of Table 4 presents the value of the semimajor axis of the ellipse described by the second harmonics of expansion and which can be expressed in terms of the spatial integrals $\tau_0\gamma_3$ and $\tau_0\gamma_4$: $A_p = \tau_0({\gamma_3}^2 + {\gamma_4}^2)^{1/2}(1 + cos^2 i)$. The same value ($A_p$) can be represented by a function of several physical parameters of the system: $A_p \sim n_e \sim \dot{m}_{WR}$ (n_e is the electron density of the envelope, $\dot{m}_{WR}$ is the mass loss rate of the WR star) (St.-Louis et al., 1988).

From the examination of the Table 4 data, it can be seen that neither in the analysis of the 1984–1986 observations nor in that of 1989 observations the condition of orthogonality of the axes of the ellipses described by the first and second harmonics of expansion, i.e. $\Delta\Omega = |\Omega_1 - \Omega_2| = 90°$, was complied with. This suggests that neither estimate of i_{polar} can be trusted.

The values of the parameters $\tau_0 G, \tau_0 H, A_p \sim n_e$ that characterize the features of the distribution of matter in the WR envelope and its density proved to be rather similar in both analyses and not standing out from the series of analogous results obtained for other WR binaries. In spite of this, comparison of three series of polarimetric studies of HD 211853 permits one to assume that in the observations of the 1980s St.-Louis et al. (1988) and Polyakova (1993) found the pair (WN6+O) of the multiple system being in an excited state, preceding the expulsion of the outermost parts of the WR envelope. That the latter occurred before our observations is suggested by the abrupt drop in linear polarization of the system (down to the level of interstellar medium polarization in its surroundings) at phases close to the second conjunction in the (WN6+O) pair. Apparently the O star, embedded during the preceding decade into the envelope, has got rid of it. This resulted in a sharp rise in the unpolarized luminosity of the O star, which entailed a drastic fall in the degree of polarization of radiation of the system at phases close to the second conjunction in pair "A" (O star is at the front).

The differences $\Delta u'$ exceeding in both analyses the errors of interstellar polarization determination are indicative of a significant contribution in linear polarization of HD 211853 system of the constant component related to the system itself.

5. On physical parameters of the stars of the main (WN6+O) pair of HD 211853

In conclusion of the paper we have made an attempt to refine the physical parameters of the stars of the main (WN6+O) pair of the multiple system under study. For this purpose, we have looked through numerous papers in which a question was raised of a possible relation of HD 211835 to the H II region S 132 (Smith, 1968; Georgelin and Georgelin, 1970; Crampton, 1971; Johnson, 1971; Harten et al., 1978; Chu, 1981; Miller and Chu, 1993; Brand and Blitz, 1993; Esteban and Rosado, 1995). The results of the papers by Miller and Chu (1993), Esteban and Rosado (1995) have given a conclusive evidence of relation of one of the two envelopes located in the field of S 132 ("B" envelope) to HD 211853. Besides, apart from the information on HD 211853, Table 4 of the paper by Miller and Chu (1993) contains the data on another ten stars of early spectral classes, possibly associated with the H II region S 132. The spectrophotometric distances presented for the stars in the same table show a very low scatter with respect to the mean value, r = 3.18 kpc, which made the authors draw a conclusion that the stars belong to one physical association. But approximately at the same distance (r = 3.4 kpc) and in the same coordinates, the association Cep OB1 is located. And what is more, two stars from Table 4 of the paper by Miller and Shu (1993) (No.4 and No.13) belong to the association Cep OB1 (stars No.23 and No.25 from the list of Humphreys (1978)). A conclusion suggests itself that HD 211853 and other stars of early spectral classes lying in the field of S 132 do not form any particular association but are members of the association Cep OB1. It appeared that van der Hucht et al. (1988) were right that referred HD 211853 to the members of this association after Lundström and Stenholm (1984). The inclusion of six additional stars of early spectral classes with known spectrophotometric distances in the list of stars of the association Cep OB1 (Humphreys, 1978) did not change $\bar{r}$ = 3.4 kpc ($m_0 - M_V$ = 12^{m}7). As to the relation of the H II region S 132 to the association Cep OB1, as it seems to us, there is no definite answer yet. In the paper by Esteban and Rosado (1995) this relation is confirmed with reference to the paper by Chu (1981), however, we have not found the estimate of the radial velocity for the main body of S 132 in Chu (1981). Based on the results of earlier

Table 5: *The estimates of absolute visual magnitudes of the WN6 components, pairs "A" and "B", and of the system on the whole obtained under different assumptions of the spectral class of the O star of pair "A"*

$Sp\,O_{\text{"A"}}$	O6V	O7V	O8V	O9V
$M_{V(O,\text{"A"})}$	-5^m4	-5^m2	-4^m9	-4^m5
$M_{V(WR,\text{"A"})}$	-5^m1	-4^m9	-4^m6	-4^m2
$M_{V,\text{"A"}}$	-6^m0	-5^m8	-5^m5	-5^m0
$M_{V,\text{"B"}}$	-5^m5	-5^m3	-5^m0	-4^m6
$M_{V(HD211853)}$	-6^m5	-6^m3	-6^m0	-5^m5

Table 6: *Possible values of the WR component mass, ratio of masses of the components and the distance between their centres obtained with the most probable mass of the O star of pair "A" ($m_O \approx 25 m_\odot$) and really admissible values of the pair orbit inclination ($i = 55° - 75°$)*

$i°$	55	60	65	70	75
$m_{WR}(m_\odot)$	3.7	5.9	8.1	9.9	11.7
$q = m_{WR}/m_O$	0.15	0.24	0.32	0.40	0.47
$a_{WR} + a_O(R_\odot)$	45.5	46.6	47.5	48.6	49.6

investigations (Georgelin and Georgelin, 1970), S 132 is then a background region with respect to the association Cep OB1, that is, it lies behind. However, the radial velocity and distance estimates presented for the body of S 132 in the paper by Brand and Blitz (1993) ($V_r = -48.5 \pm 1.5$ km/s $\rightarrow r = 4.2 \pm 1.5$ kpc) suggest that everything is possible, because the accuracy of the estimates is low.

Using the relation of HD 211853 to the association Cep OB1 ($\bar{r}$ = 3.4 kpc), the evaluation of the visual stellar magnitude (V= 9^m) presented for the system in the paper by Hjellming and Hiltner (1963), and also the estimate of the total extinction, A_V = 2^m5 (see Section 3 of this paper), we have determined the absolute visual magnitude of the system as $M_{V(HD211853)} = -6^m2$.

It follows from Massey (1981) that the companion of the WN6 star in "A" pair has an early O spectrum and luminosity class V. Under different assumptions concerning the spectral class of the O component of pair "A" we have made estimates of the absolute visual magnitude for the WN6 component, "A" and "B" pairs, and, finally for the system as a whole. All of them are collected in Table 5. The calibration of Straizis and Kuriliene (1991) ($S_p - M_V$) were used.

The estimates for $M_{V(WN6,\text{``A''})}$ and $m_{V\text{``B''}}$ were obtained from the relationships of luminosities of individual components of the system derived by Massey (1981) from the analysis of spectra of HD 211853: the WN6 star is by $\approx 0^m.3$ fainter than its O companion and pair "B" is by $\approx 0^m.1$ brighter than the O star of pair "A". A comparison of the Table 5 data with the estimate of M_V of the system following from its membership in the Cep OB1 association attests that the most probable spectral class of the O star in pair "A" is O 7 V ($M_{V(O,\text{``A''})} = -5^m.2$). The absolute magnitude of the WN6 component of pair "A" ($M_{V(WN6,\text{``A''})} = -4^m.9$) obtained here falls well within the range of absolute visual magnitudes of WN6 stars ($M_{V(WN6)} = -5^m.2 \pm 0^m.5$) (Nugis, 1988). The absolute bolometric magnitude of a star of spectral class O 7 V (Straizys and Kuriliene, 1991) is $M_{bol} = -8^m.8$. Entering this value of M_{bol} into the mass–luminosity relation deduced by Svechnikov (1985) from the main components of semidetached binary systems,

$$(lgm = 0.466 - 0.105\, M_{bol}),$$

find that the most likely value for the mass of the O component of pair "A" is

$$m_{O(\text{``}A\text{''})} \approx 25 m_{\odot}.$$

Given the mass function

$$f(m)_{WR} = m_O{}^3 sin^3 i/(m_{WR} + m_O)^2 = 10.64 m_{\odot}$$

and the estimate $a_{WR} sini = 32.6 R_{\odot}$ obtained by Massey (1981) from the radial velocity curve of WR component, and bearing in mind that atmospheric eclipse of the O star by the envelope of the WR component occurs in pair "A", we have calculated the mass of the WR star, the ratio of the masses of the system components ($q = m_{WR}/m_O$) and the distance between their centres ($A = a_{WR} + a_O$) with really admissible values of the orbit inclination of the system ($55° \leq i \leq 75°$). All of them are collected in Table 6. Considering that the ratio of the masses of the components for the majority of the WR binaries lies in a rather narrow region ($0.3 \leq q \leq 0.6$), we excluded from further inspection the calculations performed for $i < 65°$. The values of $i > 75°$ seem to us unlikely either, as at a distance between the centres of the components $\approx 50 R_{\odot}$ and real dimensions of the stars of the pair ($R_O \approx 10 R_{\odot}$ and $R_{WR\ nucleus} \approx 5 R_{\odot}$) they suggest the presence of the stellar eclipses on the light curve of the system. Thus, at $m_O \approx 25 m_{\odot}$ the most likely mass value of the WN6 component lies within the region $m_{WR} = 8 - 12 m_{\odot}$, the distance between the component centres is 47–50$R_{\odot}$, and $q = 0.32 - 0.47$.

6. Conclusions

The main result of our polarization observations of HD 211853 carried out in 1999 is the detection in the system of significant long-term (on a scale of years) variations of linear polarization. After CQ Cep, this is a second system with a Wolf-Rayet component, in which large ($\approx 1\%$) variations of the polarization curve amplitude are observed in the course of time. The sharp drop in P, leading to the deepening of the second minimum on the polarization curve of HD 211853 in the 1999 observations, and the disappearance of the primary maximum on the polarization curve of CQ Cep in the observations of 1996 (Kartasheva et al., 1998) seem to us to be due to one and the same reason. It consists in the expulsion of the uppermost parts of the WR star envelope causing the brightening of the O component. Indeed, the abrupt drop in P is observed in both systems in conjunctions when the O component is at the front of the WR star. The difference in the manifestation of one and the same phenomenon is caused by the fact that in CQ Cep — the closest of (WR+O) pairs, as well as in another two following it in closeness of the systems (CX Cep and HD 311884), the polarization curve behaves itself in a "mirror" fashion with respect to the light curve: P_{max} is reached in conjunctions, that is, when the light is minimum, and P_{min} is in elongation, when the light is maximum. See the paper by Kartasheva et al. (1998) where this feature of the polarization curves of the closest WR binaries is described in more details. That is, in the case of HD 211853 the fall of P is superimposed on the polarization minimum, while, in the case of CQ Cep it is superimposed on the polarization maximum. However in long-term variations of P of these two systems, there are also considerable differences probably caused by the fact that the WR envelope in CQ Cep is a common envelope of the system at the same time.

Unfortunately, we have not managed to solve the problem of the accurate value of the orbit inclination of pair "A". Our data were insufficient to make a Fourier analysis. When analysing the observations of St.-Louis et al. (1988) and Polyakova (1993), we found that the criterion $\Delta\Omega = |\Omega_1 - \Omega_2| = 90°$ is not satisfied, which causes mistrust in the estimates of i_{polar} obtained in these two studies.

Our examination of papers devoted to the question of possible belonging of HD 211853 to the H II region S 132 made it possible to draw a conclusion that the system is a member of the association Cep OB 1. Basing on this inference and on the results of Massey (1981), we have found the most likely masses of the components of the main (WN6+O) pair ($m_O \approx 25 m_{\odot}, m_{WR} = 8 - 12 m_{\odot}$) and the distance between its component centres ($A = 47 - 50 R_{\odot}$) when $i = 65° - 75°$. Further polarimetric and spectroscopic investigations of the system are required to make more accurate estimates of the physical parameters of the stars of the (WN6+O) pair.

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Appendix

The log of the polarization observations of V 444 Cyg that we performed in September of 1999

J.D.⊙ (2400000+)	Φ in frac. of P	$q(\%)$	$u(\%)$	$P(\%)$	Θ°
51437.414	0.750	+0.339	-0.646	0.730	148.8
51437.424	0.753	+0.269	-0.539	0.602	148.2
51439.244	0.185	+0.156	-0.599	0.619	142.3
51439.252	0.187	+0.124	-0.538	0.552	141.3
51439.360	0.212	+0.117	-0.490	0.504	141.7
51439.417	0.226	+0.216	-0.553	0.594	145.7
51439.424	0.228	+0.188	-0.475	0.511	145.8
51439.452	0.234	+0.155	-0.486	0.510	143.8
51439.461	0.236	+0.207	-0.611	0.645	144.3
51439.506	0.247	+0.239	-0.530	0.581	147.1
51440.448	0.470	+0.005	-0.372	0.372	135.4
51440.511	0.486	-0.116	-0.356	0.375	125.9
51440.518	0.487	-0.114	-0.380	0.397	126.7
51441.363	0.688	-0.028	-0.507	0.508	133.4
51441.370	0.689	+0.098	-0.556	0.565	140.0
51441.427	0.703	+0.263	-0.585	0.641	147.1
51441.435	0.705	+0.189	-0.606	0.635	143.7
51441.520	0.725	+0.269	-0.607	0.664	146.9
51441.527	0.727	+0.105	-0.570	0.580	140.2

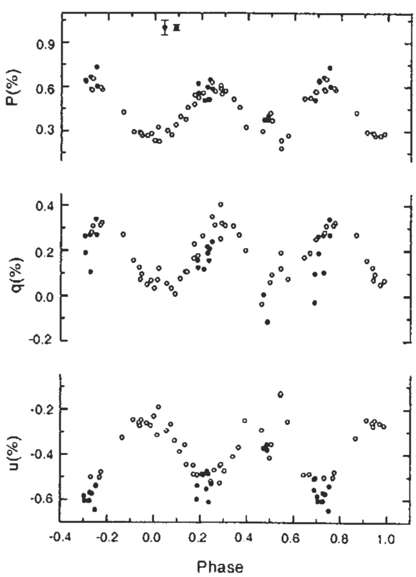

Figure 2: *The curves of variation of linear polarization (P), Stokes q and u parameters with phase of the orbital period plotted for V 444 Cyg from the results of our observations of 1999 September (filled circles). The open circles represent the results of Robert et al. (1990) (1985–1986 observations).*