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ASTRONOMY AND ASTROPHYSICS

The variability of the WC 9 Wolf-Rayet star HD 164270*

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Summary. We present and discuss *VBLUW* and *uvby* photometry of the variable WC 9 star HD 164270 made in 1981–1983. The light variation with an amplitude of $\sim 0\overset{m}{.}1$ does not show the double wave with $P = 1\overset{d}{.}7556$ as Isserstedt and Moffat (1981) found in their observations. The large intrinsic scatter superimposed on the double wave is probably one of the reasons for which it is not obvious in our data. A period analysis reveals no other candidate periods. Small colour variations are detected in the *VBLUW* photometry up to $\sim 0\overset{m}{.}02$.

Key words: photometry – variable stars – Wolf-Rayet stars

1. Introduction

HD 164270 (WR 103 in the WR catalogue of van der Hucht et al., 1981) is the brightest Wolf Rayet star of type WC 9 and of special interest because of its light variation and the suggested presence of a low-mass companion (Isserstedt and Moffat, 1981). Their spectroscopic and photometric study revealed a cyclic low amplitude radial velocity and light variation with a period of $1\overset{d}{.}7556$.

Lundström and Stenholm (1982) noted in 1980 a remarkable gradual fading of over a magnitude during the course of twenty nights. They interpreted this as a possible eclipse by a large body. On archival plates Massey et al. (1984) found an other eclipse which had occured in 1909. They give an extended discussion on the possible physical parameters of the hypothetical companion.

We present and discuss *VBLUW* (Walraven system) and *uvby* (Strömgren system) photometry in order to investigate light- and colour variations and to find further evidence for a cyclic light variation.

2. The observations and reductions

The observations were made in two photometric systems: the *VBLUW* system of Walraven and the *uvby* system of Strömgren. Those in the *VBLUW* system were made by M.D.P. van der Bij (July 1981) and by L. de Lange (April 1983) with the 90-cm Dutch telescope at the ESO, La Silla, Chile. The diaphragm aperture was 16″ and the variable was measured 5–10 times per night alternated by the comparison star HD 158528 (A5 v). This star was regularly used by Pel (1976) as a comparison star for the Cepheid V 482 Sco. In view of the smooth light- and colour curves, HD 158528 must be considered as a suitable comparison star. Typical integration times were 1 or 2 min. A detailed description of the *VBLUW* system is given by Walraven and Walraven (1960), Rijf et al. (1969) and Lub and Pel (1977).

Table 1 lists the J.D. and the nightly averages HD 164270 minus HD 158528 (in log intensity scale) for the brightness and colour indices. During the last two nights the observations were repeated at an interval of a few hours as is clear from the table. The variable did not vary this short a time scale. Corrections for differential extinction were applied whenever necessary. Standard deviations for the nightly averages are usually $\lesssim \pm 0.001$. Table 2 lists the *VBLUW* data of the comparison star obtained by a comparison with the standard stars. The V of the *UBV* system (with subscript J and in magnitude scale) was obtained with the aid of the formula (Pel, 1983):

$$V_J = 6.889 - 2.5[V + 0.039(V - B)]$$

The $(B - V)_J$ is transformed from $V - B$ with the aid of the formula: $(B - V)_J = -0.016 + 2.582\ (V - B)$ and valid in the range $-0.4 < (B - V)_J < 0.2$, (Lub and Pel, 1985).

The observations in the *uvby* system were made by Stahl (April, 1983), Zickgraf (August–September 1983) and Ott (September 1983) with the 61-cm Bochum telescope at ESO, La Silla, Chile, as part of Sterken's program "Long term photometry of variables" which is under way at ESO. The diaphragm aperture was 18″. Details of the reduction procedure is given by Manfroid and Heck (1983, 1984). Two comparison stars were used viz. HD 158582 (the same as for the *VBLUW* observations) and HD 164152. The brightnesses and colour indices of both stars are given by Manfroid et al. (1986). The relative brightnesses and colour indices of HD 164270 with respect to the first comparison star are also given by Manfroid et al. (1986). Since the variable and the two comparison stars were only measured once per night, no nightly standard deviation could be derived. We expect that for the relative brightnesses and colour indices the standard deviation is of the same order as those for the average photometric parameters of the comparison stars, thus $\pm 0\overset{m}{.}010 - \pm 0\overset{m}{.}015$.

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1986A&A...162..109V

Table 1. The photometric parameters in the *VBLUW* system of HD 164270 relative to the comparison star (in log intensity scale)

J.D. – 2440000	ΔV	$\Delta(V-B)$	$\Delta(B-U)$	$\Delta(U-W)$	$\Delta(B-L)$	Notes[a]
4788.670	−0.148	0.005	−0.263	−0.091	−0.119	
4792.690	−0.163	0.006	−0.261	−0.088	−0.118	
4793.817	−0.156	0.008	−0.262	−0.086	−0.115	
4795.625	−0.153	0.005	−0.262	−0.089	−0.118	
4798.604	−0.146	0.003	−0.262	−0.087	−0.115	
4799.635	−0.158	0.005	−0.261	−0.090	−0.116	
4802.566	−0.142	0.000	−0.263	−0.083	−0.115	
5429.875	−0.142	0.003	−0.262	−0.089	−0.116	
5445.864	−0.157	0.006	−0.263	−0.090	−0.117	1
5449.868	−0.155	0.002	−0.258	−0.089	−0.116	
5450.823	−0.168	0.010	−0.258	−0.089	−0.114	2
5450.896	−0.168	0.009	−0.259	−0.085	−0.114	2
5451.854	−0.156	0.004	−0.262	−0.088	−0.116	3
5451.882	−0.156	0.004	−0.262	−0.088	−0.117	3

[a] see Sect. 4.

3. The light- and colour variations

Similar to Isserstedt and Moffat (1981, hereafter called IM) we find that HD 164270 is variable in all passbands. The light amplitude is approximately $\sim 0\overset{m}{.}1$. IM's filters were centered at λ 3635 A (halfwidth 70 A) and λ 5170 A (190 A) and coincide the maximum of the *U* band (and the red wing of the *u* band) and the blue wing of the *V* band, respectively, where the spectrum is nearly continuous. The filters centered at λ 4680 A (130 A) and λ 5876 A (70 A) include conspicuous emission lines and are situated close to the maximum of the *b* band and the red wing of the *V* band, respectively.

IM found a correlation between the variations in the λ 4680 A (emission lines) and the λ 5170 A (continuum) bands, but uncorrelated variations in the other wavelengths.

Figure 1 shows the correlation diagrams of the relative magnitudes *uvb* against relative magnitude *y*. The scatter by noise is estimated to amount to $\pm 0\overset{m}{.}010 - 0\overset{m}{.}015$ (Sect. 2). The error bars for $\pm 0\overset{m}{.}010$ are shown in Fig. 1. It is evident that the scatter is, apart from a few exceptions, of the expected size. The scatter in the $\Delta y/\Delta v$ diagram is largest. It is hardly credible that relative variations in the emission lines can cause light variations of $\sim 10\%$ in passbands with halfwidths of 200 A or more.

Figure 2 shows the same type of diagram, but now for the *VBLUW* system (in log intensity scale). The scatter is then also much smaller and the correlation between all five passbands is excellent without a sign of any abnormal deviating point. Since all these passbands contain many emission lines, similar to the *uvby* bands (see the spectral line identifications and spectrograms of Swings (1942) and Smith and Aller (1971), respectively, it strengthens our suspicion that the abnormal points in Fig. 1 and the large scatter in the diagrams of IM must be considered as noise.

The colour variations can thus be best studied with the *VBLUW* observations. Figure 3 shows the correlation diagrams relative brightness against relative colours. There exists a clear correlation between *V* and $V-B$, a marginal one with $B-U$ (this colour index is a measure for the Balmer jump, while there is no correlation with $U-W$ (a measure for the Balmer continuum) and $B-L$ (*L* contains the Balmer limit). $V-B$ becomes bluer by ~ 0.01 with a visual brightness increase of ~ 0.03.

For hot early type stars a temperature change has only a minor effect on the optical colour indices because the optical is near the Rayleigh-Jeans limit. Only a small gradual increase in the light amplitudes occurs towards shorter wavelengths. Observations of optical micro variations of highly luminous stars show that the hotter the stars are, the smaller this gradual increase is and practically absent above $T_{\rm eff} \sim 30\,000$ K (van Genderen, 1986). The small difference in light amplitudes of the *B*, *L*, *U* and *W* channels is like those of the highly luminous O type stars, but the relatively large difference between those of the *V* and *B* channels is odd (Fig. 3 upper panel).

Table 2. The photometric parameters of the comparison star HD 158528 in the *VBLUW* system (in log intensity scale) and in the *UBV* system (in magnitude scale and with subscript *J*). Errors are standard deviations

V	$V-B$	$B-U$	$U-W$	$B-L$	V_J	$(B-V)_J$
−0.601	0.116	0.378	0.158	0.200	8.38	0.01
±0.008	±0.001	±0.003	±0.002	±0.002	±0.02	±0.01

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1986A&A...162..109V

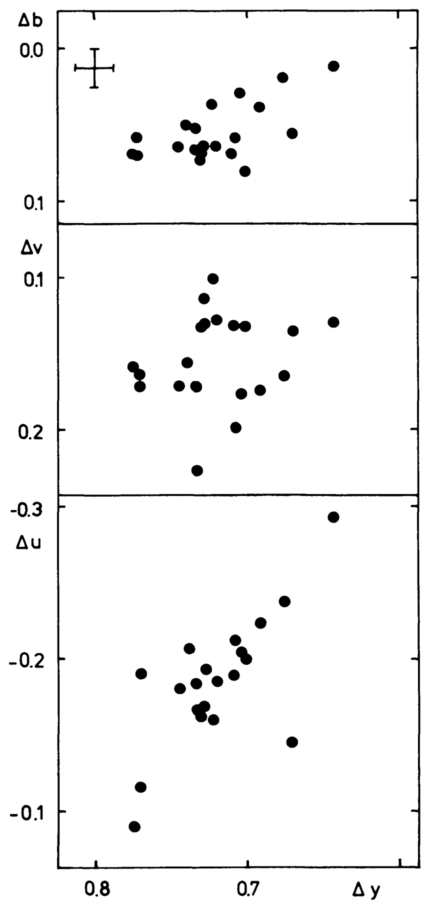

Fig. 1. The correlation diagrams of the relative magnitudes in the *uvby* system. The cross indicates errors of $\pm0^m.010$

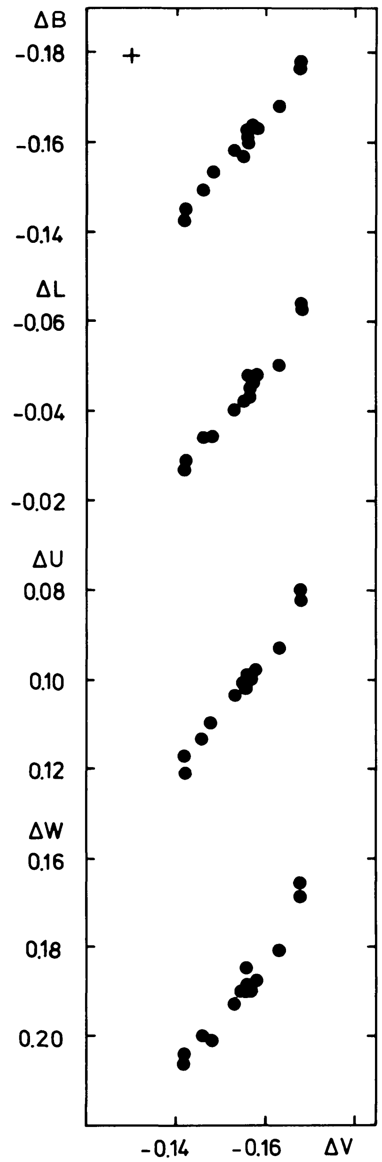

Fig. 2. The correlation diagrams of the relative brightnesses in the *VBLUW* system. The cross indicates errors of ±0.001 (log intensity scale)

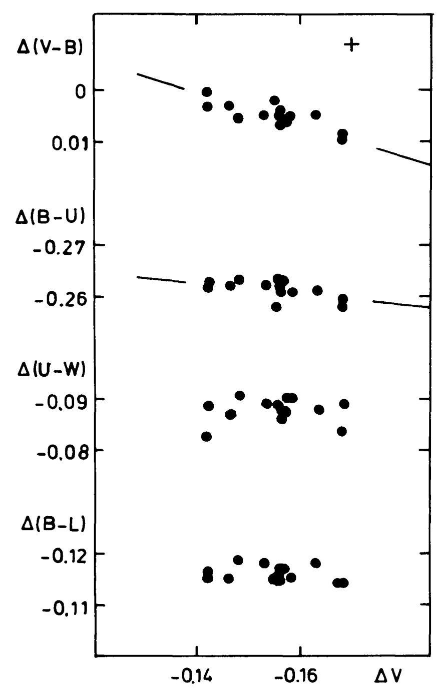

Fig. 3. The correlation diagrams relative brightness against relative colours of the *VBLUW* system (bright is to the left and blue is up)

4. A discussion on the period and the light curves

IM analysed their four channel photometry from 1976 and the radial velocity variations from 1977. Figure 4 (first panel) shows their double waved light curve for λ 5170 A relative to the comparison star (individual observations) for $P = 1^d.7556$. It looks reasonably convincing. The second and third pànels show the phase diagrams for our y (in mag) and V (in log intensity scale) observations, respectively, relative to the comparison star (the brightness scales have the same sizes). The same period, but a different zero point, which is the same for the y and V data sets, have been used. On three occasions *uvby* and *VBLUW* observations were made during the same night. They are labeled with the numbers 1–3 in Fig. 4 as well as in Table 1. The differential brightness differences of the two systems are consistent. The *VBLUW* observations labeled 2 and 3 are double, because the observations were done twice in the night. The nearly constant brightness during these intervals confirms the small standard deviation of $\leqq \pm 0.001$ of the nightly averages. This fact does not make the presence of an ultra short period (say $P < 0^d.1$) likely.

No obvious cyclic double wave is present in the two new data sets, *unless one adopts a large intrinsic scatter* superimposed on the double wave. Such a large intrinsic scatter appears to be a conspicuous character of Wolf-Rayet stars with possible companions, see for example the stars observed by Cherepashchuk and Aslanov (1984). New observations by Moffat et al. (1985) of HD 164270 seem to support the presence of a double wave, but again with a large scatter.

It is suggested that light variations such as the intrinsic scatter mentioned above of Wolf-Rayet stars, could be seen in the context of nonradial pulsations (Vreux, 1985). However as Maeder (1985) pointed out, radial oscillations should be substantially greater than non-radial ones. It is however the question whether one

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1986A&A...162..109V

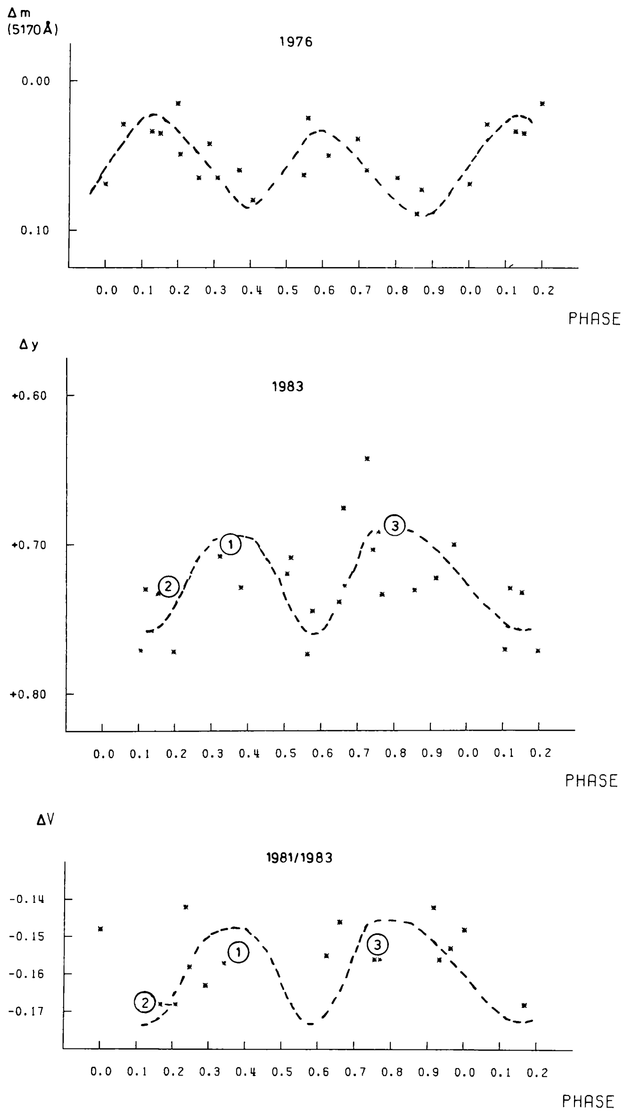

Fig. 4. The phase diagrams with $P = 1^{\rm d}.7556$ for the observations of Isserstedt and Moffat (1981) (upper panel), of the y (*uvby* system observed by Stahl, Zickgraf and Ott, central panel) and V (*VBLUW* system observed by van der Bij and de Lange, lower panel) observations

can see any vibrational instability due to the thick envelope surrounding Wolf-Rayet stars, which prevents us from seeing much from the star itself. This suggestion made by Maeder is substantiated by (unpublished) *VBLUW* photometry of a large number of Wolf-Rayet stars, which, compared with theoretical colours based on model atmospheres, indicate too low temperatures compared with the theoretical models ($T_{\rm eff} \sim 100000$ K) by a factor of five or so. Besides, the temperatures and gravities derived from different two-colour diagrams are not consistent at all. Thus, the continua received from Wolf-Rayet stars are presumably seriously affected by the dense envelopes and consequently, the cause of the intrinsic scatter must perhaps be sought elsewhere.

In the Δy and ΔV panels of Fig. 4 we sketched roughly a double wave, which more or less fits our (too low number of) observations and accepting the presence of an intrinsic scatter by an order of magnitude larger than the errors. Thus the zero point is by no means certain and must be considered as arbitrary.

Nevertheless to be certain we searched our two data sets and that of IM for other periods. Therefore we applied Sterken's (1977) and Stellingwerf's (1978) period of search programs on the three data sets separately for the interval $0^{\rm d}.5-5^{\rm d}.0$, (only the visual data of our two new sets were used). The search with Sterken's method was done with steps of $0^{\rm d}.001-0^{\rm d}.01$. The search with Stellingwerf's method was done with bin structures of 5,2 or 5,5 and step numbers of 100–500. A number of candidate periods were found with r and θ values signficant enough to construct a phase diagram. A few of them revealed a one wave light curve in one or two data sets, but the scatter was often still too high. Besides none of these candidate periods fitted all three data sets. We also tried periods close to $0^{\rm d}.88$ and $1^{\rm d}.75$, but also without success. In order to treat both new data sets as one single set, we combined the y and V observations by transforming ΔV into Δy with the aid of the observations labeled 1–3 in Table 1 and Fig. 4. Then not even one candidate period emerged from the analysis. We suppose that if the period of IM is real (and the new observations of Moffat et al. may support that), phase gaps and the large intrinsic scatter have masked it completely. In view of the facts that the number of observations is too low and the precise shape of the double wave as well as the zero point are unknown, it is impossible to investigate the intrinsic scatter for a periodicity.

5. Conclusions

With two new photometric data sets of the WC 9 star HD 164270 obtained in 1981–1983, we confirm the light variations of the order of $0^{\rm m}.1$ as found by IM. Presumably due to phase gaps, a too low number of observations and a large *intrinsic* scatter, we cannot confirm a double wave with a period of $1^{\rm d}.7556$ as claimed by IM. The double wave, the existence of which (Moffat et al., 1985) remains to be proved, may be caused by the presence of a companion. But any interpretation should also explain the large intrinsic scatter. The cause of the intrinsic scatter, nearly as large as the amplitude of the double wave, is unknown yet, but appears to occur often in the light curves of Wolf-Rayet stars (with compact companions?) (Cherepashchuk and Aslanov, 1984).

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1986A&A...162..109V

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