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A Spectrophotometric Study of the Wolf-Rayet Star HD 50896

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Abstract. New spectrophotometric observations of the Wolf-Rayet system HD 50896 are presented and interpreted in terms of its binary nature. The lines of N v, N iv and C iv show moderate variations, which can be explained using a binary model with a compact companion. He ii λ4686 appears to arise from a larger region compared to other lines. The distortion caused by the wind can partly explain its flux variations. The emission fluxes of He i lines are generally constant indicating their non-participation in the orbit. The results are compared with other Wolf-Rayet binaries (V444 Cyg and CQ Cep) and the evolutionary status is discussed.

Key words: Stars, Wolf-Rayet—stars, binary, interacting—stars, individual

1. Introduction

HD 50896 (= EZ CMa, V = 6.94, WN5) is the sixth brightest star in the catalogue of Wolf-Rayet stars (van der Hucht *et al.* 1981). Spectral and light variability have been reported by many earlier investigators (Wilson 1948; Smith 1955; Ross 1961; Kuhi 1967). Night-to-night variations of He ii λ4686 were reported by Smith (1968), Irvine & Irvine (1973) and Schmidt (1974), though none of these studies led to a positive conclusion on the binary nature. Serkowski (1970) reported strong polarimetric variations which were confirmed by Mc Lean *et al.* (1979) and Mc Lean (1980). Small amplitude photometric variations of 3.76 d period were reported by Firmani *et al.* (1979) and confirmed by Cherepashchuk (1981), although the shapes of the light curves did not agree. The line profiles are found to vary over time scales of a few hours (Ebbets 1979; Firmani *et al.* 1980; Singh 1984). More recent precision photometry (Lamontagne, Moffat & Lamarre 1986) has revealed a complex (but stable) modulated light curve.

The most recent and detailed spectroscopic and photometric studies are due to Ebbets (1979), Firmani *et al.* (1980), Cherepashchuk (1981) and Lamontagne, Moffat & Lamarre (1986), who point to the binary nature of the system with a compact companion of mass about 1–2 $M_\odot$, although other mechanisms like nonradial pulsations and rotation were offered as possible but less likely explanations for the light and emission line behaviour. The binary model goes in tune with the evolutionary scheme of a WR binary in a post-X-ray-binary stage (van den Heuvel 1976; Tutukov & Yungelson 1979), and therefore makes it a particularly interesting system for study.

The study of emission lines offers an opportunity for understanding the envelope structure and its asymmetry caused by the presence of the companion. Spectrophotometric studies of CQ Cephei, a very close WN7 binary, showed that the emission-line flux variations are dependent on the stellar wind structure and Roche surfaces modified to take into account the extended wind structure (Shylaja 1986a, Paper I). In the present analysis of HD 50896, a similar investigation is carried out with the aim of understanding the possible atmospheric stratification and the effect of the companion on it. Section 2 describes the observations and results. The flux variations and a possible model are discussed in Section 3. Section 4 compares the results with other known eclipsing binaries and discusses the evolutionary status.

2. Observations and results

The observations were obtained with the spectrum scanner (Bappu 1977) containing a 600 line mm^{-1} grating blazed at 7600 Å, at the Cassegrain focus of the 102 cm reflector of the Vainu Bappu Observatory, Kavalur, during 1983–85. A channel spacing of 5 Å, in the second order blue region ($\lambda\lambda$3800–4900) and of 10 Å in the first order green to red region (λ4800 to 7100) were employed. The entrance aperture was about 24 arcsec in diameter. An exit slot of 800 μm was used, corresponding to a resolution of 10 Å in the second order and 20 Å in the first order. The spectrophotometric standards taken from the lists of Hayes (1970) and Breger (1976) were observed every night to derive the extinction coefficients and for the determination of absolute flux.

Although HD 50896 is within the boundary of the open cluster Collinder 121, doubts have been expressed about its membership (*cf.* Firmani *et al.* 1980), because of the difference between the age of the cluster Cr 121 and of the other clusters known to contain WR stars. At the same time, the reddening of the stars in Cr 121 is small ($E(B-V) \sim 0.0$), not making it a distinctive feature of HD 50896 exclusively, for which it has been shown that the reddening corrections are small (Hillier 1984). Hence all the flux and magnitude measurements reported here, are not corrected for reddening. Fig. 1 shows sample scans at different orbital phases.

2.1 *Emission-Line Flux*

The flux of some emission lines of He I, He II, N IV, N V and C IV were measured from the scanner results. N III λ4640 flux was too weak to be measured. N V λ4603 merged with the other N V λ4620. The type of profile variations of He II λ4686 and N IV λ4058 described by the previous investigators could be clearly seen on some occasions in spite of the lower resolution of only 10 Å. In the longer wavelength region, C IV λ5808–12 was generally stronger than He I λ5876, but only on some occasions was the latter stronger than the former. Some line blends at λ4200 and λ4540 were also measurable, although the individual contributors to these blends could not be resolved. The atlas of Smith & Kuhi (1981) was used as a guide to draw the line profiles. Figs 2 and 3 represent these flux variations.

Hillier (1984) discusses the influence of electron scattering on He II line profiles. Bappu (1973) had attributed the red wing of the He II (7-4) line at λ5410 to an unidentified transition, because this was not seen in the other members of the Pickering series. Hillier shows that this is due to electron scattering and the effect is apparent in other He II lines also. It was also noticed that these red wings can lead to erroneous continuum and line-flux measurements. To avoid this, only the relative line-flux ratios are compared (Table 1, Figs 2 and 3), to see the possible effect of binarity. He II λ4860

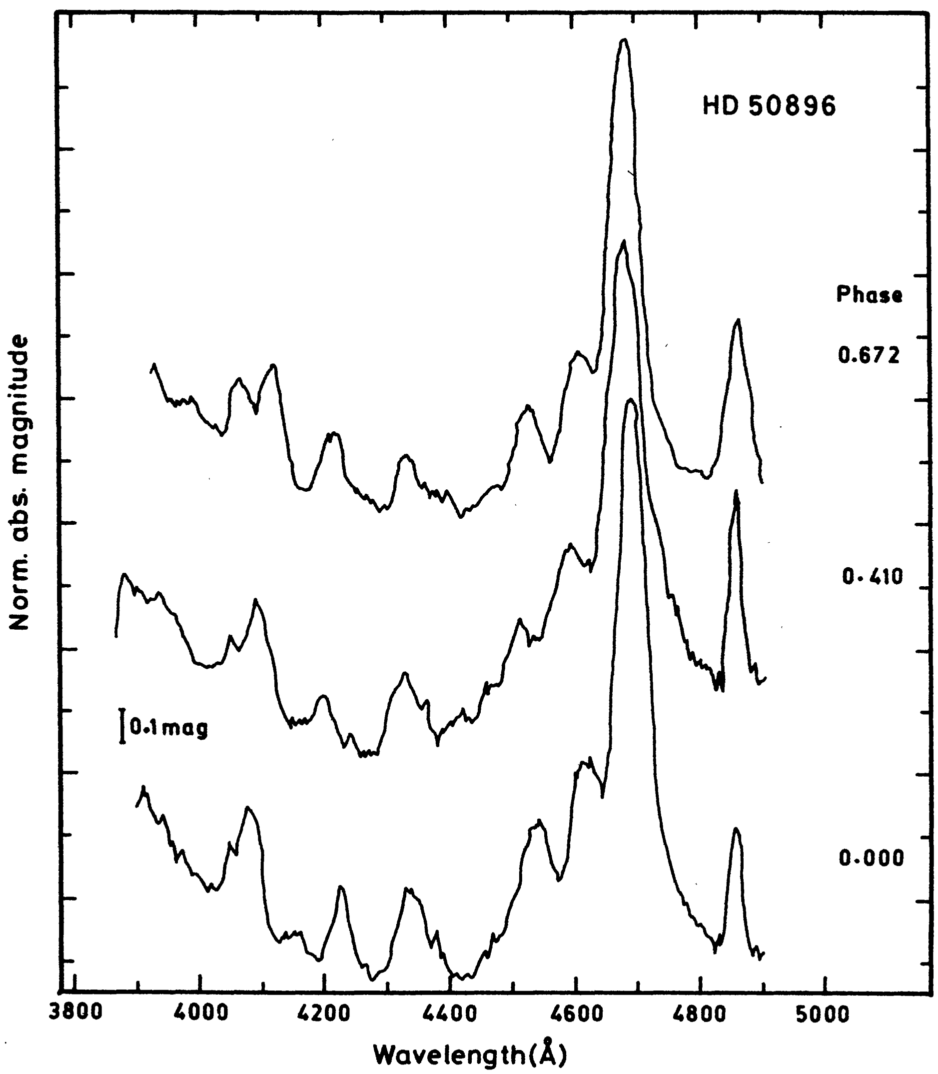

Figure 1. Sample scans of HD 50896 in the blue region. The derived absolute magnitudes are normalized to at 5000 Å.

was chosen for taking the flux ratios because it was generally covered on all occasions. The scatter of the flux of λ4860 (Fig. 2) may represent an intrinsic variation of flux for the system, which makes it difficult to isolate the variations caused by the binary nature.

3. Line flux variations and model

Many recent detailed spectroscopic investigations have established the reality of the time-dependent changes in line profiles. Although it was not possible to see the profile variations very clearly because of the low resolution in our scans, the phase dependent changes in flux are clearly seen. High dispersion spectra show the finer details of such changes (Firmani *et al.* 1980). Two peaks of the emission lines merge at

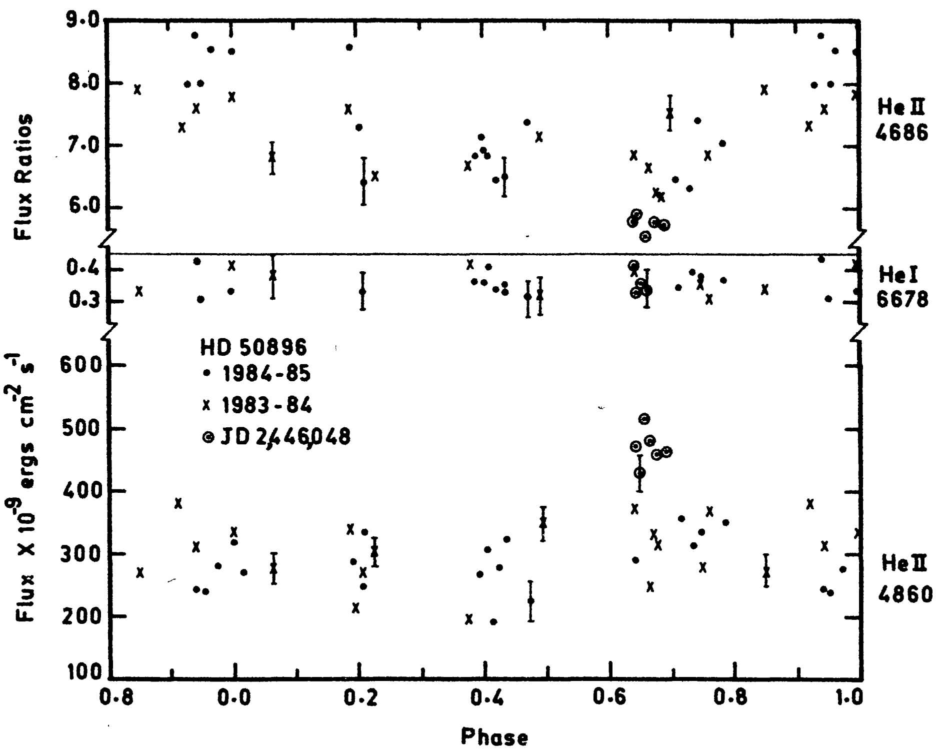

Figure 2. Flux variation of the He II lines λ4860 and the flux ratio for λ4686 and He I λ6678. Note the sudden change in flux at phase 0.68 and its absence for 4686 line. The zero phase is calculated at JD 2,445,752.279 and 2,446,072.146 separately for each season.

phase 0.5. N IV λ4058, which is considered to be very stable and deemed to represent the motion of the WN component in the narrow-lined WNL stars (Moffat & Seggewiss 1979), shows largescale profile variations in the broad lined WN5 star HD 50896 (Firmani *et al.* 1980). On the other hand, N IV λ3483 is very stable, although it is a blend of a number of multiplets. It may also be noticed that N V λ4603 does not undergo this kind of splitting and merging in profiles. The flux of this line shows a clear variation over the 3.763 d period. Hence the phase has been calculated using this as reference. The folding of the data was done separately for every season, choosing the minimum value of the λ 4603 flux to correspond to phase 0.0, similar to the definition of Firmani *et al.* (1980).

It is apparent from Fig. 2 that He II λ4860 shows a scatter around a mean value. Perhaps this scatter reflects the intrinsic variations. The other lines expressed as ratios relative to this line may be grouped into two catagories—those with no variations over the orbital period, and those with noticeable variations. He II λλ5410, 6562 show insignificant changes implying variations similar to λ4860. The flux of N V λ4603 exhibits a relatively sharp dip, from which the zero phase was defined. N IV λ4058 and C IV λ5808 also show a similar dip, but of lower amplitude. It may be noticed that the flux of He II λ4686 behaves differently with a larger scatter and exhibits somewhat higher flux at phase ~ 0.9. The line blends at λλ4540 and 4200 have variations of flux ratio similar to the He II lines (Table 1), possibly because the main contributor is He II itself.

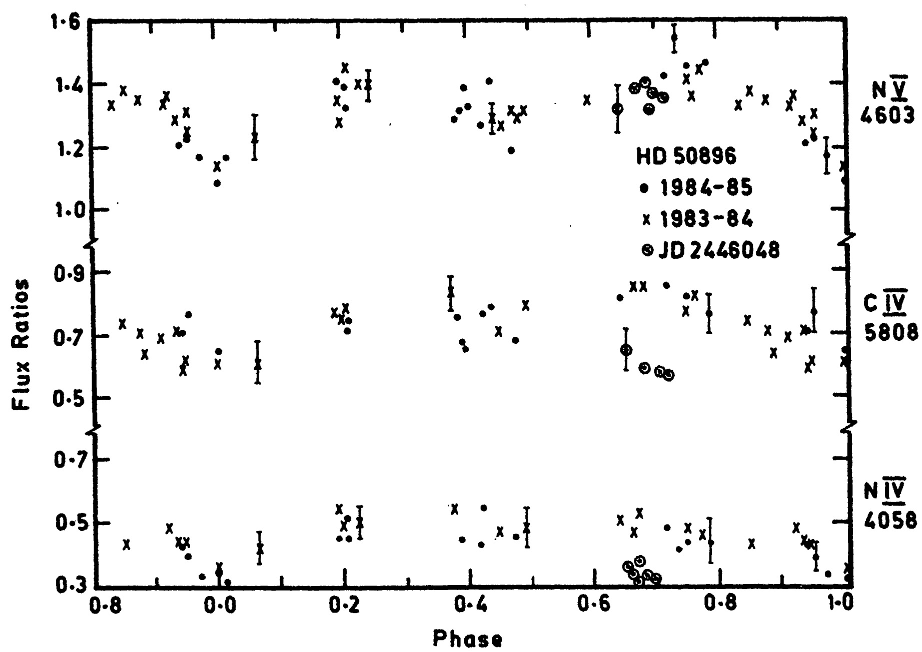

Figure 3. Flux variation of N v λλ4603–20, N IV λ4058 and C IV λ5808. All are expressed as a ratio relative to 4860 line flux. Calculation of phases are same as described in Fig. 2.

As was seen in the case of CQ Cep (Paper I), if we were to assume that N v originates closest to the core, the reduction in flux at phase 0.0 can be immediately attributed to the possible eclipse effects. This requires the size of the companion to be large enough to partially cover the line-emitting region. However, the estimated mass from the mass function derived from the radial velocity curves is very small. This argument of the higher excitation lines originating closer to the photosphere holds for the line-emitting regions of the N IV and C IV also.

The observed scatter in the flux (*e.g.* λ4860) implies the presence of intrinsic variations. On the other hand, the existence of orbital effects is apparent in the variations of flux ratios, which agree with the period of 3.763 d. These facts lead to a model of asymmetric distribution of matter around the WR component exhibiting an intrinsic variation in addition to eclipse effects.

We may start with the model suggested by Firmani *et al.* (1980), which is based on precise radial velocity measurements. None of these radial velocity curves gives a circular orbit although the N v line gives a smaller value of e. The light curve also does not clarify this point. Therefore, we start with an eccentric orbit. The classical Roche surfaces have been found to be inapplicable in binaries with large wind velocities (Paper I). We see a single prominent minimum in λ4603 flux variation. (Firmani *et al.* (1980) have found an indication of a second minimum on one occasion, which is not very prominent in our results.) This restricts the sizes of the line emitting regions of N v, N IV and C IV closer to the WN component.

Although there is one spurious increase at phase ~ 0.65 on one epoch, He II λλ5410, 6562 and 4860 show no phase-dependent variation of total flux. The presence of only random variations implies that either the line-emitting regions are varying intrinsically

Table 1. Flux Ratios of HD 50896 relative to 4860A Line.

JD 2440000 +	Phase	N IV 4058	Blend 4100	Blend 4540	He II 4686	He II 5410	C IV 5810	He I 5876	He II 6562	He I 6678	N V 4620	He I 7065	He II 4860
5254.375	0.684	0.40	0.77	1.22	7.69	—	—	—	—	—	1.28	—	375.0
5254.401	0.691	—	—	—	—	1.59	0.76	1.15	1.76	0.31	—	2.31	351.0
5254.432	0.700	0.36	0.75	1.17	7.55	—	—	—	—	—	1.31	—	375.0
5330.204	0.835	0.39	0.84	1.15	6.88	—	—	—	—	—	1.33	—	345.0
5330.221	0.840	0.38	0.86	1.21	6.92	—	—	—	—	—	1.31	—	310.0
5330.234	0.843	0.40	0.75	1.31	7.12	—	—	—	—	—	1.29	—	335.0
5330.246	0.847	—	—	—	—	1.69	0.74	1.21	1.75	0.34	—	2.33	340.0
5330.259	0.850	0.43	0.78	1.10	7.92	—	—	—	—	—	1.38	—	308.0
5330.309	0.863	0.39	0.80	1.25	7.62	—	—	—	—	—	1.35	—	328.0
5330.321	0.867	0.36	0.86	1.15	7.42	—	—	—	—	—	1.40	—	345.0
5330.361	0.877	—	—	—	—	1.75	0.71	1.28	1.69	0.31	—	2.46	295.0
5330.374	0.881	0.34	0.82	1.11	7.37	—	—	—	—	—	1.35	—	309.0
5330.396	0.887	—	—	—	—	1.64	0.81	1.31	1.73	0.36	—	2.76	325.0
5370.141	0.449	—	—	—	—	1.69	0.81	1.35	1.62	0.29	—	2.65	305.0
5370.162	0.454	0.47	0.91	1.36	8.11	—	—	—	—	—	1.27	—	355.0
5370.175	0.458	0.45	0.88	1.29	8.07	—	—	—	—	—	1.25	—	347.0
5370.192	0.462	0.41	0.86	1.17	7.56	—	—	—	—	—	1.29	—	329.0
5370.236	0.474	0.44	0.85	1.22	7.92	—	—	—	—	—	1.31	—	336.0
5370.251	0.478	0.39	0.68	1.36	7.65	—	—	—	—	—	1.29	—	370.0
5370.271	0.483	0.45	0.71	1.28	7.55	—	—	—	—	—	1.31	—	365.0
5370.292	0.489	—	—	—	—	1.62	0.79	1.21	1.75	0.33	—	2.70	358.0
5370.307	0.493	0.49	0.82	1.32	7.12	—	—	—	—	—	1.33	—	349.0
5405.128	0.746	—	—	—	—	1.58	0.77	1.25	1.81	0.37	—	2.54	295.0
5405.140	0.750	0.48	0.95	1.36	7.53	—	—	—	—	—	1.41	—	289.0
5405.156	0.754	—	—	—	—	1.62	0.68	1.19	1.91	0.36	—	2.46	280.0
5405.167	0.757	0.47	0.87	1.22	7.89	1.81	0.59	1.06	—	—	1.36	—	265.0
5405.183	0.761	0.44	0.91	1.31	6.82	1.75	0.72	1.12	—	—	1.31	—	315.0
5405.197	0.765	—	—	—	—	1.66	0.75	1.20	1.88	0.31	—	2.59	368.0
5405.210	0.768	0.40	0.86	1.28	6.95	—	—	—	—	—	1.23	—	320.0
5405.223	0.772	0.46	0.92	1.29	7.51	—	—	—	—	—	1.26	—	350.0
5452.092	0.227	0.51	0.88	1.35	6.51	—	—	—	—	—	1.40	—	304.0

5602.462	0.187	0.54	0.54	0.86	7.58	1.41	0.77	1.08	—	—	1.38	—	340.0
5649.421	0.665	0.47	0.82	1.36	6.63	1.58	0.85	1.17	—	—	1.32	—	246.0
5649.439	0.671	0.43	0.87	1.28	6.17	1.62	0.89	1.23	—	—	1.29	—	330.0
5649.464	0.677	—	—	—	—	1.54	0.86	1.21	1.81	0.44	—	2.69	317.0
5650.373	0.919	0.41	0.61	1.07	7.17	1.71	0.79	1.19	—	—	1.34	—	370.0
5650.376	0.920	0.48	0.59	1.13	7.32	1.68	0.77	1.06	—	—	1.36	—	382.0
5650.380	0.921	—	—	—	—	1.53	0.69	1.13	1.79	0.41	—	2.56	360.0
5650.386	0.922	0.43	0.71	1.08	7.33	1.62	0.62	1.16	—	—	1.26	—	375.0
5650.390	0.923	0.44	0.68	1.18	7.28	1.77	0.68	0.97	—	—	1.31	—	368.0
5650.437	0.936	0.43	0.63	0.97	7.53	1.59	0.73	1.03	—	—	1.29	—	382.0
5650.441	0.937	—	—	—	—	1.63	0.71	0.89	1.76	0.43	—	2.63	340.0
5650.445	0.938	0.46	0.57	1.16	7.33	1.68	0.66	0.95	—	—	1.29	—	362.0
5650.458	0.942	—	—	—	—	1.75	0.59	0.91	1.78	0.44	—	2.68	310.0
5650.468	0.944	—	—	—	—	1.80	0.61	1.11	1.76	0.41	—	2.72	355.0
5650.467	0.943	0.43	0.64	1.15	7.54	1.65	0.65	1.08	—	—	1.31	—	355.0
5650.472	0.945	0.42	7.54	0.96	7.35	1.78	0.68	1.02	—	—	1.24	—	338.0
5651.412	0.195	—	—	—	—	1.58	0.75	0.93	1.66	0.39	—	2.68	330.0
5651.419	0.197	0.39	0.64	0.86	7.41	1.49	—	—	—	—	1.28	—	275.0
5651.439	0.202	0.33	0.64	0.97	7.38	1.62	—	—	—	—	1.26	—	305.0
5651.443	0.203	0.36	0.49	0.88	7.22	1.67	—	—	—	—	1.29	—	315.0
5651.451	0.205	—	—	—	—	1.65	0.78	0.97	1.59	0.44	—	2.66	320.0
5752.279	0.000	0.36	0.58	1.03	7.81	1.51	0.61	1.05	1.91	0.41	1.14	—	278.0
5790.158	0.066	0.42	0.62	0.83	7.97	1.56	0.61	0.89	1.88	0.38	1.23	—	295.0
5810.147	0.378	0.45	0.63	1.21	6.69	1.71	0.83	1.12	1.85	0.42	1.29	—	372.0
5811.139	0.641	0.51	0.89	1.06	6.83	1.55	0.79	1.08	1.76	0.41	1.44	—	375.0
6037.475	0.786	0.44	0.85	1.17	7.06	1.56	0.76	0.98	1.98	0.37	1.47	—	355.0
6047.260	0.387	0.46	0.55	0.99	5.95	1.46	0.76	0.96	—	—	1.22	—	285.0
6047.268	0.389	—	—	1.19	6.13	1.49	0.68	1.08	1.83	0.41	1.39	2.61	276.0
6047.277	0.391	0.49	0.53	0.96	6.22	1.48	0.77	1.07	—	—	1.33	—	210.0
6047.284	0.393	—	—	—	—	1.53	0.66	1.16	1.85	0.36	—	—	255.0
6047.317	0.402	0.43	0.69	1.11	7.13	1.65	0.75	1.03	—	—	1.41	—	190.0
6047.325	0.404	0.47	0.68	1.16	6.90	1.71	0.73	1.13	—	—	1.33	—	310.0
6047.349	0.410	0.45	0.68	1.23	6.85	1.68	0.74	0.87	—	—	1.38	—	240.0
6047.393	0.422	0.51	0.74	1.08	6.45	1.49	0.69	0.95	—	—	1.27	—	255.0
6047.400	0.424	—	—	—	—	1.59	0.77	0.92	1.91	0.34	1.36	2.54	278.0
6047.438	0.434	0.55	0.77	0.93	6.45	1.39	0.82	0.97	—	—	1.41	—	325.0

Table 1. Continued

JD 2440000 +	Phase	N IV 4058	Blend 4100	Blend 4540	He II 4686	He II 5410	C IV 5810	He I 5876	He II 6562	He I 6678	N V 4620	He I 7065	He II 4860
6047.446	0.436	—	—	—	—	1.46	0.79	0.96	1.92	0.35	—	—	259.0
6048.213	0.640	0.37	0.78	1.17	5.82	1.53	0.68	0.69	—	—	1.32	—	431.0
6048.218	0.641	—	—	—	—	1.55	0.68	0.75	1.72	0.38	—	2.73	475.0
6048.224	0.643	—	—	—	—	1.58	0.59	0.73	1.68	0.33	—	2.81	520.0
6048.236	0.646	0.36	0.69	1.32	5.92	1.47	0.59	0.72	—	—	1.37	—	515.0
6048.252	0.650	—	—	—	—	1.63	0.65	0.64	1.90	0.39	—	2.79	507.0
6048.261	0.653	0.41	0.63	1.20	5.28	1.44	0.65	0.63	—	—	1.33	—	482.0
6048.300	0.663	—	—	—	—	1.47	0.56	0.69	1.65	0.34	—	2.70	475.0
6048.309	0.665	0.43	0.83	1.26	5.81	1.59	0.67	0.66	—	—	1.36	—	502.0
6048.333	0.672	0.41	0.79	1.28	5.35	—	—	—	—	—	1.39	—	486.0
6048.341	0.674	0.46	0.76	1.38	5.77	—	—	—	—	—	1.33	—	495.0
6048.359	0.679	—	—	—	—	1.46	0.59	0.81	1.93	0.42	—	2.68	506.0
6048.376	0.683	0.41	0.91	1.33	5.93	1.41	0.86	0.79	—	—	1.40	—	465.0
6048.401	0.690	0.39	0.94	1.34	5.74	1.53	0.83	0.68	—	—	1.41	—	480.0
6048.429	0.697	0.38	0.87	1.43	5.86	1.62	0.84	0.80	—	—	1.32	—	462.0
6048.445	0.702	—	—	—	—	1.58	0.78	0.82	1.55	0.39	—	2.74	481.0
6048.466	0.707	0.32	0.75	1.28	5.33	1.80	0.54	0.63	—	—	1.36	—	465.0
6048.491	0.714	—	—	1.30	5.21	1.75	0.57	0.71	1.53	0.36	1.39	2.80	335.0
6072.146	0.000	0.37	0.47	0.86	8.53	1.42	0.65	0.85	1.62	0.33	1.09	—	318.0
6083.217	0.942	0.43	0.86	0.92	8.77	—	—	—	—	—	1.21	—	358.0
6083.259	0.953	0.39	0.83	1.17	7.98	1.77	0.77	1.21	2.17	0.31	1.23	2.19	390.0
6083.337	0.974	0.33	0.81	0.85	7.97	—	—	—	—	—	1.23	—	345.0
6083.493	0.015	0.39	0.68	1.22	8.56	—	—	—	—	—	1.26	—	332.0
6148.115	0.189	0.45	0.45	0.84	8.59	0.97	0.76	0.49	—	—	1.41	—	285.0
6148.180	0.206	0.51	0.60	0.93	7.32	0.79	0.72	0.85	—	—	0.83	—	246.0
6150.094	0.714	0.48	0.91	1.05	5.89	1.49	0.86	0.71	1.81	0.34	1.43	—	358.0
6150.172	0.735	—	—	—	—	1.78	0.78	0.67	2.07	0.39	1.55	2.72	312.0
6150.218	0.747	0.44	0.88	0.94	7.40	1.81	0.84	0.60	2.12	0.38	1.46	—	335.0
6197.102	0.207	0.45	0.89	0.84	6.38	1.64	0.75	0.90	—	—	1.33	—	336.0
6198.110	0.474	0.46	0.65	0.96	7.37	1.66	0.68	1.21	1.73	0.31	1.19	—	226.0

or the asymmetry is caused by the companion. The same argument holds for the He I lines also, which show relatively constant values of flux with respect to He II λ4860. Generally (as also in CQ Cep) all the He I lines have associated violet absorption edges at high V_∞ implying their origin in the outermost parts of the envelope. The absence of orbital effects in He I lines agrees with their origin in a region surrounding both the components and not participating in the orbital motion.

The behaviour of the He II λ4686 line is different from other lines. On one occasion (JD 2,446,048 . . .), when there was enhancement of flux at all lines, this line did not show an increase. Although He II λ4686 shows significant scatter the flux increases near phase 0.0, there is a general variation of flux from season to season as seen by Firmani *et al.* (1980) also. Two explanations are possible for this: (1) According to the model shown schematically by Firmani *et al.* (1980), the compact star will be closest to the WN star near phase 0.15. This could lead to an increase in the flux close to this phase. (2) The production of He II λ4686 is not confined to any selected zone of the atmosphere, but is produced throughout the envelope, so that at phase 0.0 we see maximum intensity of this line, by virtue of maximum line-emitting material lying completely unocculted towards the observer. The line profile also changes at this phase to one with a sharp peak and extended wings.

With the radial-velocity orbital solutions and the resulting mass function, one may derive a mass of 1–2 $M_\odot$ for the compact star assuming the mass of the WN component to be 10 $M_\odot$ and $i = 70°$. The separation is of the order of 20 $R_\odot$. If we adopt the measurements of V444 Cyg (WN5 + O) (Cherepashchuk, Eaton & Khaliullin 1984) for the size of the core and extent of the atmosphere of the WN5 component, the extension of the atmosphere in HD 50896 will be comparable to the separation itself. The compact star although considerably distant from the WN core in this case, cannot cause significant changes in either spectral line profiles, or in the continuum energy distribution. The accretion onto it can produce X-rays but they can become degraded to lower energies because of the dense electron envelope (Moffat & Seggewiss 1979). More recently, Vanbeveran, van Rensberger & de Loore (1982) have considered the production mechanism as well as the absorption of X-rays and discussed the different reasons for the non-detection of X-rays.

Thus we may say that the binary model proposed by Firmani *et al.* can explain the flux variation of emission lines. N V, N IV and C IV originate closer to the core in a highly ionized region (Moffat & Seggewiss 1978, 1979; Sahade 1980). As noted by Firmani *et al.*, the lines of He II at λλ5410, 6562 and 4860 originate in a region farther from the core. This region is distorted by the companion and therefore the flux measures of the He II lines result in a greater scatter. The region of He I line emission is outermost, probably enclosing the companion.

4. Discussion

The well-studied binary V444 Cyg has an orbital period close to that of HD 50896. Direct comparison between the two is not possible because of the differences in the type of the companion. In the case of V444 Cyg, the companion is O type, which eclipses the WN component at phase 0.5. All the emission lines show eclipse effects at both minima. The concentration of the He II emitting material is clearly shown by the line profiles (Ganesh, Bappu & Natarajan 1968). In the case of HD 50896, the companion is smaller, not producing any noticeable eclipse effects either in the continuum or in line fluxes. Its influence in the distortion of the extended atmosphere can be noticed only for N V, N IV and C IV lines. Other lines show only some scatter about the mean flux.

There are some similarities between the two systems. None of the radial velocity curves for different emission lines gives identical solutions in either case. Both the systems show variation of polarization with orbital phase; therefore, it is possible that HD 50896 has also a dense electron envelope similar to V444 Cyg. Such polarization changes are noticeable in the case of CQ Cep also (Drissen *et al.* 1986).

The peculiarity of He II λ4686 line in CQ Cep and V444 Cyg indicates its origin in a region extended through the wind (Paper I). The same is also true for N III λ4640 in those stars. In HD 50896 this line was too weak to be measured. N IV λ4058 showed stable symmetric profiles in V444 Cyg (Ganesh, Bappu & Natarajan 1968) and in CQ Cep (Bappu & Viswanadham 1977); in HD 50896, the profile was double-peaked and changed throughout the orbit (Firmani *et al.* 1980).

The wind-dominated Roche surface can explain the flux variations for CQ Cep and also partly for V444 Cyg (Paper I). In the case of HD 50896 there is a complication introduced not only by the intrinsic variation, but by the asymmetric distribution as well. The eccentricity of the orbit adds to this. The value of $e = 0.34$ is based on the radial velocity measures of N IV λ3483 emission. However, the radial velocity of absorption edge of N V λ4621 gives a still smaller value of e, but shows significant phase shift (Firmani *et al.* 1980), and therefore the exact value of the orbital eccentricity is difficult to specify. It is known that the λ4686 radial velocity curve usually gives an eccentric orbit solution in WN binaries (Shylaja 1986b) and therefore, other N V lines will have to be studied for establishing the true value of e.

Smith (1973) suggested that all Population I WR stars have masses 10 $M_\odot$ and that they all evolved from more massive stars. More recently, Massey (1981) has shown that the mean value of the mass of WR stars is $\sim 20\ M_\odot$. Since hydrogen deficiency is a general feature of all WR stars (Sahade 1981), it was also postulated that the outer hydrogen material has been lost. The evolutionary scheme of de Loore (1980) invokes two stages of WR phase in a binary. The first phase corresponds to the more widely known WR + OB phase; the second is the WR + compact phase, after a supernova explosion. In the case of a binary, it is possible that the mass from the WR star is accreted onto the companion, making it more massive and readily detectable (Paczyński 1967). However, the winds are so fast that the accretion may be negligible. When the companion is less massive and not detectable, the material is more readily lost to the surroundings and may appear like a nebula. Therefore, Wendker *et al.* (1975) attributed the presence of the nebulae in NGC 6888 to the material ejected from HD 192163, which was considered to be a single star. Recently, its binarity has been suggested (cf. van der Hucht *et al.* 1981), but remains uncertain (Vreux, Andrillat & Gosset 1985).

In the case of HD 50896, the binary nature is postulated based on radial velocity and flux variations, although intrinsically varying supposedly single stars also are known (*cf.* van der Hucht *et al.* 1981). The presence of the compact companion puts HD 50896 in the class of the second WR phase in the scenerio proposed by de Loore (1980). Another feature which would facilitate confirmation of this aspect is the space velocity. It is generally believed that the binary pulsars with high space velocities result from supernova explosions in a binary with dissimilar components. It is also derived that, depending on the mass lost, the circular orbit may change to one with high eccentricity and a close binary may arise without being disrupted (van den Heuvel 1976; Shylaja & Kochhar 1984). The large distance of HD 50896 from the galactic plane also favours the idea. The association with the ring nebula S 308 (Chu *et al.* 1982), which indicates the nitrogen enrichment, puts its origin to the WN star itself (Kwitter 1984). Recently, a large interstellar structure has been detected in the line of sight towards HD 50896 (Heckathorn & Fesen 1984).

5. Conclusions

This spectrophotometric study of HD 50896 shows that the lines of N V, N IV and C IV display moderate variations which may be interpreted in terms of a binary model of the system. Because of the eccentric orbit and nondetection of eclipse effects in light variations, quantitative derivations of the orbital parameters are not possible. From the radial velocity determinations available, it appears that the companion is a compact star. Comparison with other eclipsing systems like V444 Cyg and CQ Cep shows that the atmospheric structures are similar. The He II lines probably arise from a region distorted by the presence of the companion. The λ4686 line of He II has a different behaviour as in other eclipsing systems. The He I lines generally have constant flux, indicating their formation outside the influence of the companion.

The association with a nebulosity and the location relatively far from the galactic plane may suggest assigning HD 50896 to the second WR binary phase as a post-SN event. Other techniques like systematic fast photometry and measurement of space velocity may yield important information on the type of companion and the accreting process.

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