On the Nature of the Two Supergiant Components in the System of V 810 Cen = HR 4511 = HD 101947

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**Summary.** V 810 Cen = HR 4511 = HD 101947 is a yellow variable supergiant on the blue side of the Cepheid Strip. Photometric characteristics and recent IUE satellite spectra indicated the presence of a blue supergiant companion. On account of spectroscopic, photometric and evolutionary considerations, the companion has likely a $T_{\text{eff}}$ of 25,000–30,000 K. With this temperature and the $V$–$B$/$B$–$L$ diagram of the $VBLUW$ system it is tried to determine the range of $M_v$, $T_{\text{eff}}$, $\log g$ and unreddened photometric parameters of both stars. The spectral type of the cool supergiant could be F7.5.

**Key words:** variable stars – supergiants – binaries – $VBLUW$ photometry

1. Introduction

In a recent paper the yellow variable supergiant V 810 Cen = HR 4511 = HD 101947 ($P \approx 125^d$), hereafter called V 810 Cen A, was discussed together with two other cool supergiants in and near the instability strip of the Cepheids (van Genderen, 1980 hereafter called Paper I). Eichendorf and Reipurth (1979) discussed the possibility that the yellow component may be a Cepheid with an extremely long period. The Walraven $VBLUW$ photometry discussed in Paper I, clearly demonstrated the presence of a blue companion, hereafter called V 810 Cen B. This was confirmed by IUE satellite spectra (Eichendorf, 1979; Parsons, 1981, and Eichendorf et al., 1981). By fixing the photometric parameters of V 810 Cen A in the $VBLUW$ system assuming its spectral type to be G0 I with $(B-V)_0 = 0.73$ (the subscript J refers to the UBV system), the photometric parameters of the blue companion have been computed. They correspond with a star of $T_{\text{eff}} = 10,000$ K. However, the IUE spectra of the references just mentioned, clearly show that the temperature is much higher: at least 20,000 K. Parsons proposes two possibilities: a high luminosity star of $M_v \sim -6$ ($M_{\text{bol}} \sim -8$), based on characteristics of the UV spectrum, or a star of $M_v \sim -4.6$ ($M_{\text{bol}} \sim -7$) based on a continuum fitting procedure. Eichendorf et al. suggests for the hot companion a spectral type of B0.5–1 Iab or Ib. Consequently V 810 Cen A should have an earlier spectral type than G0 and a colour index $(B-V)$ appreciably bluer than 0.73. However, a recent catalog of Keenan and Pitts (1980) which provides a list of stars carefully classified on the Revised MK system gives G0–Ia Fe I, meaning that the star is superluminous with a slightly stronger ironline strength than normal.

In this paper it is tried to determine more precisely the nature of both members of the binary, starting with the high IUE temperatures of the blue companion and the two-colour diagram $V$–$B$/$B$–$L$ of the $VBLUW$ system, which allows to discriminate (to a certain extent) between different models.

2. The Models

Figure 1 shows the three two-colour diagrams of the $VBLUW$ system with the observed loop of V 810 Cen A (Paper I). The open circle is one observation by Pel (1976). The asterisk is the unreddened position using $E_{B-V} = 0.26 \pm 0.04$ according to Moffat and Vogt (1975) and highly consistent with the extinction dip near 2200 A (Parsons, 1981) and previous work (Parsons and Bell, 1975). The black dot on the boundary of the G1-II area is the position of V 810 Cen A according to the model of Paper I, but since the blue companion has $T_{\text{eff}} = 10,000$ K. Since, as we know $T_{\text{eff}}$ lies somewhere between 20,000–30,000 K, V 810 Cen A should be much bluer and of an earlier spectral type than G0. Presumably between F6 and F9. Since F type supergiants should obey practically the same narrow locus as for the Cepheids (see first panel in Fig. 1) one is able to compute the limits of $M_v$ and $T_{\text{eff}}$ of the blue companion. This Cepheid locus is taken from Pel (1978). By subtracting the appropriate possible candidates, V 810 Cen A should be displaced onto the locus.

[The small difference between the Cepheid locus of Pel and the locus of F type supergiants (non-Cepheids) mentioned in Paper I, may be caused by the fact that theoretical two-colour diagrams have been used based on a microturbulent velocity $v_t = 2$ km s$^{-1}$, while the true $v_t$ is presumably somewhat larger.]

The three sloping lines in Fig. 1 demonstrate the effect on the position of V 810 Cen A, when a number of models for the blue companion are subtracted (to prevent confusing, only three are shown). They are in order of increasing steepness: $T_{\text{eff}} = 20,000$, 22,500, and 25,000 K, all with $log g = 3$ and for four different values of $M_v$, viz. $-4.0$, $-4.25$, $-4.5$ and $-5.0$ (indicated in the upper panel). It is obvious that within this range of the temperature, $M_v$ should not be brighter than $-4.25$. Not much changes, if $log g$ is slightly altered, say into $log g = 2.5$ or 3.5. If $T_{\text{eff}} = 30,000$ K and $log g = 3.5$, $M_v$ should not be brighter than $-3.75$. These models are basically not much different from the one of Parsons, based on the continuum fit and that of Eichendorf et al. viz. an early evolved B type star with $M_v \sim -4.6$. Parsons' second model based on the UV characteristics: $M_v \sim -6$, and also a B type star is ruled out according to the photometrical restrictions.

For the computations we made use of the theoretical two-colour diagrams of Lub and Pel (1977) and Brinks et al. (1979)
Fig. 1. The two-colour diagrams of the $VBLUW$ system (in log intensity scale). The $B-V$ index of the $UBV$ system (with subscript $J$) is indicated as a comparison. Further are shown: the observed loop of $V$ 810 Cen A (Paper I), an observation of Pel (1976) (circle), the dereddened position of the system $V$ 810 Cen using $E_{(B-V)J} = 0.26$ mag (asterisk), the Cepheid locus/area, the area of G-I-II supergiants and the main sequence ($V$).

Fig. 2. The theoretical HR diagram of Stock 14 (taken from Parsons, 1981) with the theoretical evolutionary track of a $20 M_{\odot}$ star without mass loss (solid line) and with mass loss (dashed line). The open circle is a Be star. The estimated ranges of the blue component according to the models of Parsons (1981): (dashed and solid parallelogram), of Paper I (plus sign) and this paper (hatched area and crosses). The range of the yellow component is also indicated together with the $P-L-C$ relations of variable supergiants according to Maeder (1980) for $P=100$ and $125^d$.

Based on the model atmospheres of Kurucz (1975). The micro-turbulent velocity is taken to be $v_{\text{mic}} = 2$ km s$^{-1}$. A higher value has only a minor effect on the $v_{\text{mic}}$ effect on the yellow star is discussed in Sect. 3.

3. The Position in the Theoretical HR Diagram

Figure 2 depicts the theoretical HR diagram of Stock 14 containing the system $V$ 810 Cen (copied from Parsons). The position of the blue companion, according to the models between $T_{\text{eff}} = 20,000$ and 30,000 K, lies within the hatched area. The effect on the position of $V$ 810 Cen A is only small, which is now at the blue side of the Cepheid strip. [This is in contrast with the proposed model of the blue companion in Paper I (plus sign), resulting in a position for $V$ 810 Cen A within the strip.]

The effect on the blue companion by taking a lower reddening $E_{(B-V)J} = 0.24$ instead of 0.26, is illustrated by the row of crosses. ($M_{\text{bol}}$ gets brighter by $\sim 0.3$ mag), that of $V$ 810 Cen A gets fainter by $\sim 0.08$ mag while the temperature of $V$ 810 Cen A decreases by $\sim 100$ K.

The solid parallelogram contains Parsons' model obtained by flux fitting ($M_{\text{c}} - 4.6$). The dashed parallelogram is for his model based on the UV spectrum ($M_{\text{c}} - 6$) and which is ruled out in view of the photometric considerations and Eichendorf et al.'s IUE spectra.

On account of the distribution of the other evolved members of the cluster, the temperature limits of the blue companion may be perhaps put between 25,000 and 30,000 K. Table 1 then summarizes the rough range for the photometric and physical parameters for both the components ($E_{(B-V)J} = 0.26$ mag). Since no atmospheric models were available of $\log g < 3.5$ and $T_{\text{eff}} = 30,000$ K, we could not try them. However, the effect on the result is expected to be small if $\log g$ is for example 3.

As said in Sect. 2, we used for transforming the unreddened $VBLUW$ parameters of $V$ 810 Cen A into $T_{\text{eff}}$ and $\log g$ at $v_{\text{mic}}$. © European Southern Observatory • Provided by the NASA Astrophysics Data System
Table 1. Most likely range of photometrical and physical parameters of both the components \((E_{(B-V)}_0 = 0.26 \text{ mag})\)

<table>
<thead>
<tr>
<th>Star and spectral type</th>
<th>(T_{\text{eff}} ) (K)</th>
<th>(M_V)</th>
<th>(V_0)</th>
<th>((B-V)_0)</th>
<th>((B-V)_V)</th>
<th>(\log g)</th>
<th>(M_{\text{bol}})</th>
<th>(\log L/L_\odot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V 810 Cen B</td>
<td>25,000</td>
<td>-4.25</td>
<td>7.82</td>
<td>-0.28</td>
<td>8.60</td>
<td>-0.02</td>
<td>3.0</td>
<td>-6.3</td>
</tr>
<tr>
<td>B1 Iab-Ib</td>
<td>30,000</td>
<td>-3.75</td>
<td>8.32</td>
<td>-0.32</td>
<td>9.10</td>
<td>-0.06</td>
<td>3.5</td>
<td>-6.6</td>
</tr>
<tr>
<td>V 810 Cen A</td>
<td>6,050</td>
<td>-7.94</td>
<td>4.13</td>
<td>0.53</td>
<td>4.90</td>
<td>0.79</td>
<td>1.8</td>
<td>-7.84</td>
</tr>
<tr>
<td>F7.5 Ia</td>
<td>6,150</td>
<td>-7.95</td>
<td>4.11</td>
<td>0.51</td>
<td>4.89</td>
<td>0.77</td>
<td>2.1</td>
<td>-7.85</td>
</tr>
</tbody>
</table>

\(=2 \text{ km s}^{-1}\). If this would be say 3 \(\text{ km s}^{-1}\), \(T_{\text{eff}}\) in Table 1 raises by 50–100 K and \(\log g\) by \(\sim 0.3\).

The colour index derived for V 810 Cen A is according to Table 1 \((B-V)_0 \sim 0.52\) mag. Using Kelsall’s (1972) calibration the spectral type then is F7.5. There is thus some discrepancy when compared with the most recent classification of Keenan and Pitts (1980) viz. GO 0–1a Fe1 (Sect. 1). Further Keenan (1980, private communication) suggested that \(M_V\) may well be \(-8.5\), while according to Table 1 \(M_V\) is at most \(-7.95\). So the situation is still somewhat unsatisfactory. It should be of interest to find out whether also the spectrum is variable, causing these discrepancies.

The two straight lines at the right top corner show the \(P - L - C\) relation for variable supergiants with \(P = 100\) and 125\(\text{s}\) according to Maeder (1980). More observations are necessary to determine the characteristic period more precisely.

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