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Is HR 2947 a variable ?

N. Kameswara Rao *Indian Institute of Astrophysics, Bangalore 560 034*

N. M. Ashok and P. V. Kulkarni *Physical Research Laboratory, Ahmedabad 380 009*

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Abstract. Observations of HR 2947 show that it is fainter by 0.3 mag in V compared to the magnitude listed by Cowley *et al.* (1969). The energy distribution from 1565 Å to 1.25 μ is similar to that of a B5 III star and does not indicate presence of any companion. $T_{eff} \simeq 13500 \pm 500$ K and $\log g = 3.5 \pm 0.5$ are obtained by comparison with the theoretical energy distribution. It is suggested that the light variability, if real, could be due to the formation of a thin gas shell around the star.

Key words : variable stars

1. Introduction

HR 2947 is classified as a B6 Vn star by Cowley *et al.* (1969), and was used as one of the comparison stars in our photometric study of HD 62001 (Rao & Gilra 1980, 1981). Subsequently we found that the star is fainter by 0.3 mag in V compared to the value given by Cowley *et al.* (1969). Moreover the magnitude of the star as given in various catalogues differs by one magnitude. The HD gives its m_v as 6.44 and the spectral type as B9, while BD gives $m_{pg} = 7.3$. According to the *Argentine General Catalogue* (1886) $m_v = 6.8$, while the *Yale Catalogue of Proper Motions* (1940) gives a value 7.4. In order to study the nature of the star and its variability, we obtained further spectrophotometric and photometric observations of the star which are discussed in this paper.

2. Observations

All our observations reported here were obtained with the 1-m telescope at Kavalur. The spectrophotometric observations of the star were obtained on 1979 December 16/17 using the photoelectric spectrum scanner described by Bappu (1977). The energy distribution between 3250 Å and 6050 Å was obtained with the photometer filter combination of EMI 9804 QB and BG 12 for the range of 3250 Å to 4475 Å (Program 1) and with GG13 for the range 4460 Å to 6050 Å (Program 2). A band width of 25 Å was used for Program 1 and 50 Å for Program 2. The flux calibration was obtained by observing the standard stars θ Crt and η Hyd on the same night (Breger 1976). The typical photometric errors are ± 0.02 mag and there might be a shift of ± 0.03 mag between Program 1 and Program 2 energy distributions. The observations are shown in Table 2.

The wide band photometry of the star was done on many nights mostly in the *B* filter with an EMI 9558B photomultiplier. However, the *UBV* observations were also obtained on a few occasions. The *UBV* magnitudes and colours obtained in 1980 January are given in Table 1. The *JHK* magnitudes of the star obtained in 1981 February using liquid nitrogen cooled InSb photometer of Physical Research Laboratory, Ahmedabad are also given. The typical errors are ± 0.05 mag.

The β index and *uvby* colours of the star have been given by Eggen (1977) and Crawford (1963). All the wide band photometric observations along with ours are listed in Table 1. Further, this star was also observed with the Ultraviolet Sky Survey Telescope (S2/68) on TD1 Satellite in the ultraviolet. The fluxes in the four UV bands are given in the Catalogue of Steller Ultraviolet Fluxes (CSUF, Thomson *et al.* 1978). These are reproduced in Table 2, along with our scanner observations.

Table 1. Photometry of HR 2947

Reference	V	$B-V$	$U-B$	$b-y$	m_1	c_1	β	J	H	K
Crawford (1963)		−0.10	−0.51				2.711			
Cowley *et al.* (1969)	6.44	−0.10	−0.51							
Eggen (1977)	6.70*			0.003	0.094	0.532	2.705			
Present										
January (1980)	6.72	−0.087	−0.476							
February (1981)								7.05	7.26	6.74

*This value is on the Eggen System.

Table 2. Scanner energy distribution of HR 2947

λ	m_λ^*	λ	m_λ	λ	m_λ
1565	4.769	3500	6.006	4475	5.947
1965	5.163	3570	6.057	4566	5.736
2365	5.607	3635	6.101	5000	6.077
2740	5.876	4035	5.586	5263	6.259
3250	5.921	4165	5.680	5460	6.376
3300	5.883	4255	5.781	5556	6.435
3350	5.926	4360	5.843	5840	6.656
3400	5.926	4464	5.913	6050	6.778

*$m_\lambda = (-2.5 \log F_\lambda - 21.175)$, F_λ in ergs cm^{-2} s^{-1} A^{-1}.
The mag for $\lambda\lambda$1565, 1965, 2365 and 2740 are from CSUF.

3. Results

The interstellar reddening of the star is estimated as follows. The CSUF gives a recipé to estimate $E(B-V)$ from the UV colours alone, provided the star is on the main sequence. This estimate gives the reddening of $E(B-V) = 0.06$. The star was classified as B6 Vn by Cowley *et al.* (1969). In this spectral range the luminosity class does not matter for the colours unless the star is a supergiant. This estimate of $E(B-V)$ is consistant with the $(B-V)$ calibration of a B5-6 star (Johnson 1966). All the observed magnitudes are corrected for this reddening using the formulae given in CSUF or in Seaton (1979). The corrected colours are given in Table 3, along with the values for the B5 III start δ Per. These values are corrected for a reddening of $E(B-V) = 0.008$.

Figure 1 shows the wide band colours for the two stars, where the squares denote δ Per. The agreement of the colours (Table 3) of δ Per with HR 2947 is very good from 1565 Å to visual, particularly in the case of observations made after 1972. The *UBV* observations listed by Cowley *et al.* (1969) are shown as triangles and fall above the energy distribution of HR 2947 observations of 1980 and also above δ Per. However, as can be seen from Table 3, the $J-K$ value of HR 2947 is different

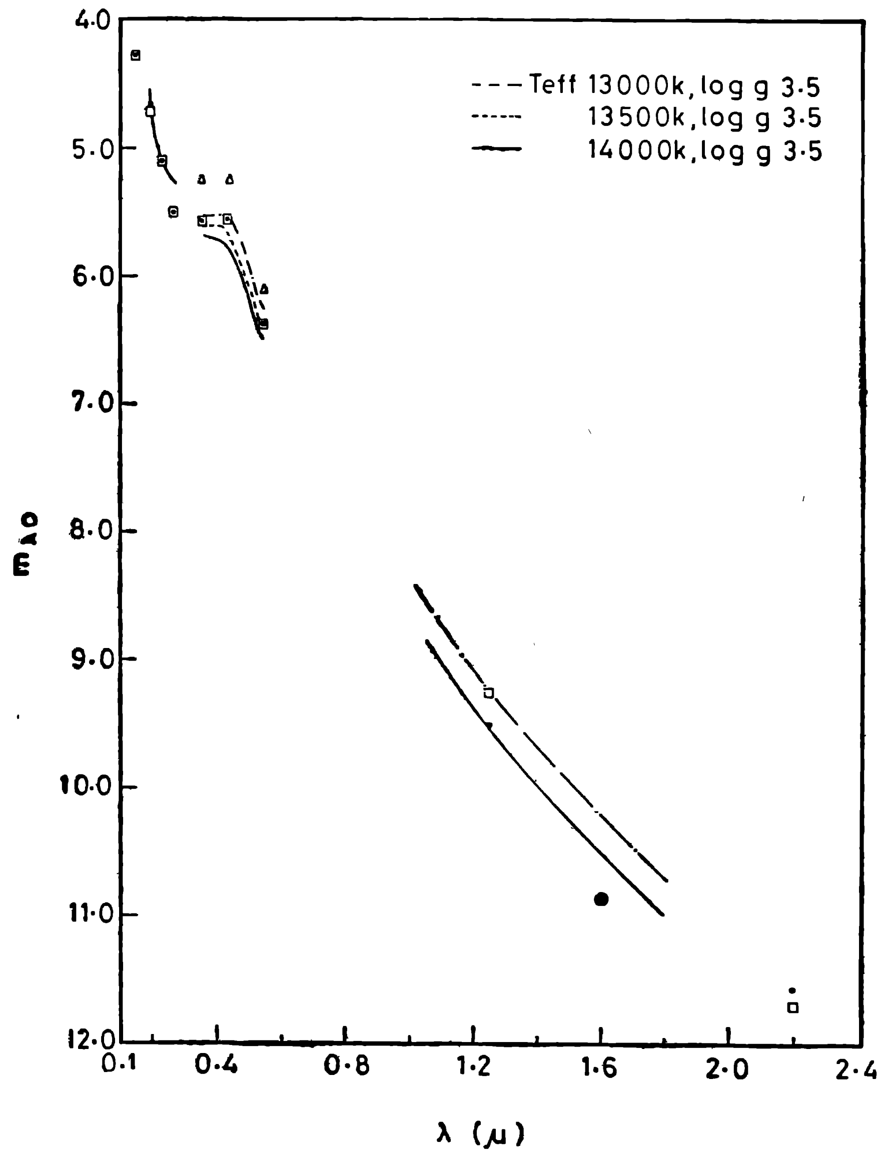

Figure 1. The energy distribution of HR 2947 (dots) after correcting for interstellar reddening and of δ Per (open squares) normalized for m_{λ_0} of HR 2947 at λ 1565. The ▲ indicates the *UBV* observations listed by Cowley *et al.* (1969).

Table 3. Unreddened colours

	$B-V$	$U-B$	$b-y$	m_1	c_1	$[m_{2740}-m_{1565}]$	$J-K$
HR 2947 :							
Cowley *e al.* (1969)	−0.160	−0.553					
Thompson *et al.* (1978)						1.23	
Eggen (1977)			−0.041	0.108	0.521		
Present (1980)	−0.147	−0.519					
Present (1981)							+0.28
δ Per (B5III)	−0.148	−0.525	−0.042	0.085	0.526	1.23	−0.104

Reddening correction for $b-y$, m_1, c_1 is from Crawford (1975).

from that of δ Per, and indicates a slight colour excess. This similarity of the energy distribution of HR 2947 and δ Per shows that the effective temperatures of both the stars are the same and are similar to that of a B5 III star. However the values of the β index of HR 2947 obtained by Crawford (1963) and Eggen (1977) (2.711 and 2.705 respectively) are greater than the β index 2.671 of δ Per. This might in turn indicate higher effective gravity for HR 2947. According to the calibration given by Egret (1978) for β index, the M_v is about − 0.7 for HR 2947 and − 1.6 for δ Per.

Further, the scanner energy distribution and the UV fluxes of HR 2947 are compared with the theoretical energy distributions computed by Kurucz (1979). These are shown in Figure 2 normalised to the observed flux at 1565 Å. Except for the point at 2740 Å the theoretical fluxes match the observed fluxes for models with $T_{eff} \simeq 13500$ K and $\log g = 3.5$. Slight variations in $\log g$ and T_{eff} can also match the observed energy distribution. The theoretical *UBV* colours computed by Kurucz (1979) match the 1980 *UBV* observations for the model $T_{eff} = 14000$ K and $\log g = 3.5$. The same model when normalized at 1565Å predicts a flux which agrees with the observed flux at *J* filter (1.25μ). Once the T_{eff} is estimated ($\simeq$ 13500 K), $\log g$ can be determined more securely as follows. From the relation between the equivalent width of Hβ and the β index (Zinn 1970), the equivalent width of Hβ is obtained as 7.55 Å for the β index given by Eggen (1977). This estimate of Hβ equivalent width gives a value of $\log g = 3.5$ from the theoretical equivalent width—$\log g$ relation calculated by Kurucz (1979). Thus the comparison with the theoretical fits of the energy distribution of HR 2947 indicates that the fluxes obtained after 1972 can be matched with model atmospheres of $T_{eff} = 13500 \pm 500$ K and $\log g = 3.5$. It should be remembered that this matching has been done with observations obtained at different times.

4. Discussion

As pointed out in Table 1 the star became fainter in *V* by 0.3 mag between (1) the observations listed Cowley *et al.* (1969) and (2) the observations by Eggen (1977) and in 1980 January by us. No change in the magnitude has been noticed since 1979. The differences in estimates of the magnitude listed in different catalogues (section 1) also show that the star could be a variable. The changes in $B-V$ and $U-B$ colours are not large and could be within observational errors. The estimates of T_{eff} and $\log g$ indicate that the star could be a β Cephei variable, a hot Ap star, a binary or a shell star. However it could not be a β Cephei type variable for the following

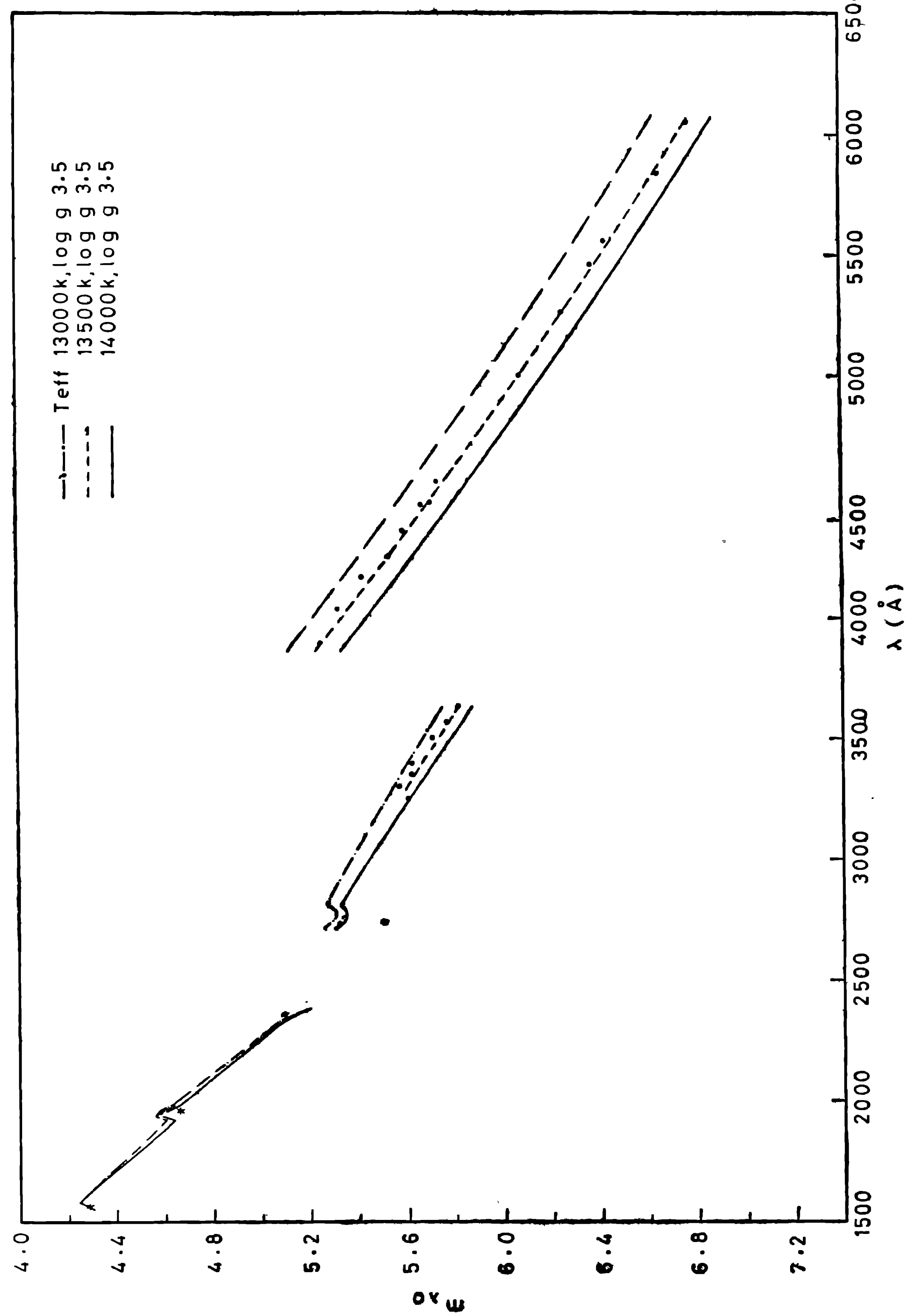

Figure 2. The energy distribution of HR 2947 after correcting for the reddening of $E(B-V) = 0.06$. m_λ for λλ1565, 1965, 2365 and 2740 are taken from CSUF. Dots indicate the scanner observations obtained 1979 December 16. The continuous lines indicate the theoretical energy distributions normalised at λ1565.

reasons. No classical β Cephei type variable has a later spectral type than B2.5 III, although Hill's (1967) suspected β Cephei stars do have later spectral types. Continuous photometric monitoring of the star for 5 to 6 hours on several nights does not reveal any periodic variations of amplitude $\Delta B \gtrsim 0.02$, which is uncharacteristic of β Cephei type stars. Moreover, the amplitude of light variation, 0.3 mag is too large for a classical β Cephei star.

In the HR diagram, HR 2947 occupies a region of hot Ap stars which are also light variables but their amplitudes are much smaller ($\Delta B \lesssim 0.1$ mag). Invoking the binary nature of the star to account for the light variability demands that the period be extremely large. The *V* observation made prior to 1977 (Eggen 1977) agree with the observation made in 1980. Also, the fact that the UV observations obtained in 1972–74 with scanner and the *UBV* observations made in 1980 agree with the single theoretical energy distribution indicates that the *V* mag is also the same for the 1972–74 period, which is 0.3 mag fainter than the values quoted by Cowley *et al.* (1969). If this variation is attributed to an eclipse, then the eclipse should continue for about 8 years or more which seems to be very unlikely. Further, the energy distribution obtained earlier does not show any excess in UV or visual region which would have been the case if a companion were present.

We now propose that if the light variability is real, it could be due to a gas shell obscuring the star. The lack of change in the *UBV* colours between the observations listed by Cowley *et al.* and the 1980 observations might suggest an electron scattering shell. The only support for this model comes from the presence of small differential infrared excess between δ Per and HR 2947. There seems to be some excess flux in the *K* band (Table 3). Such shell episodes are not uncommon in B stars. Particularly a comparison could be made with the photometric variability of HD 45677—a known Be star (Bartolini & Scardovi 1976, Swings & Allen 1971) which showed a variation of 0.4 mag in 1400 days. Also it has infrared excess at wavelengths longer than *K*.

A low dispersion (70 Å mm^{-1}) spectrogram of the blue region obtained with the 1-m telescope in 1979 March does not show any emission lines in the spectrum. It shows Balmer lines of hydrogen and He I λλ 4026, 4387 in absorption and agrees with the spectral type of B6. But λ4471 of He I appears to be weak. In this respect it is similar to WRA 795, another Be star (Vidal *et al.* 1974). Further observations of the star are planned.

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