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HD 59864: a New β Cephei-Type Variable Star[1]

by

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ABSTRACT

Photoelectric observations of HD 59864 are reported. The star is found to be a β Cephei-type variable. Frequency analysis of the data indicates that the light variation consists of two short-period components. However, frequencies of the components cannot be unambiguously derived from the present data. Four pairs of frequencies that equally well represent the data are given.

1. Introduction

HD 59864 is a 7.6 mag. B1 III star in the constellation Puppis. Its *uvby* and β indices (Kilkenny 1978, 1981) place it in the β Cephei instability strip, defined in the colour–magnitude plane by field β Cephei variables (Jerzykiewicz and Sterken 1979, Sterken and Jerzykiewicz 1983). From photoelectric observations, carried out on five nights in February and March 1986, HD 59864 was indeed found to show short period light variations typical of β Cephei stars. The present note contains an account of these observations and a discussion of the results.

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[1] Based on observations obtained at the Mt. John Observatory, Lake Tekapo, New Zealand

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2. Equipment and results

The observations were obtained by C.S. with the Optical Craftsman 60-cm reflecting telescope of the Mt. John Observatory. The equipment included a conventional photoelectric photometer, containing a standard B filter and a blue-sensitive photomultiplier tube, and pulse counting electronics . The measurements, each consisting of two to four 5 or 10 second integrations, were taken in the following order:

$$C1 \text{ sky } P \text{ sky } C2 \text{ sky } C1 \text{ sky} \ldots \quad (1)$$

where $C1$ = HD 59594 (A2), P = HD 59864, and $C2$ = HD 59527 (B8). Unfortunately, HD 59594 turned out to be a δ Scuti variable (Jerzykiewicz and Sterken 1990). Consequently, HD 59527 was left as the only comparison star. The results, in the form of differential magnitudes "HD 59864 minus

Table 1

The B filter differential photometry of HD 59864

HJD	Δm	HJD	Δm	HJD	Δm
2446000+		2446000+		2446000+	
469.9432	0.706	490.9943	0.708	496.9036	0.700
469.9572	0.699	491.0034	0.699	496.9091	0.703
469.9680	0.697	491.0111	0.710	496.9145	0.702
469.9763	0.698	491.0188	0.702	496.9198	0.699
469.9842	0.696	491.0267	0.704	496.9250	0.700
469.9937	0.692	491.0362	0.710	496.9299	0.714
470.0020	0.694	491.0451	0.711	496.9359	0.710
470.0095	0.695	491.0541	0.704	496.9413	0.702
470.0189	0.697			496.9464	0.706
470.0265	0.696	493.8807	0.713	496.9538	0.696
470.0348	0.690	493.8853	0.718	496.9592	0.701
470.0433	0.704	493.8915	0.704	496.9645	0.717
470.0515	0.709	493.8981	0.718	496.9696	0.710
470.0593	0.713	493.9039	0.715	496.9752	0.708
470.0683	0.708	493.9095	0.715	496.9804	0.715
470.0808	0.710	493.9147	0.719	496.9862	0.718
470.0897	0.708	493.9198	0.710	496.9916	0.717
470.0988	0.722	493.9249	0.710	496.9970	0.712
470.1078	0.718	493.9308	0.708	497.0021	0.708
470.1208	0.716	493.9361	0.726	497.0078	0.713
470.1297	0.695	493.9415	0.718		
470.1379	0.704	493.9465	0.714	497.8816	0.703
		493.9521	0.715	497.8887	0.699
490.9132	0.705	493.9586	0.714	497.8953	0.698
490.9205	0.699	493.9638	0.709	497.9006	0.706
490.9266	0.702	493.9688	0.709	497.9061	0.710
490.9334	0.704			497.9114	0.713
490.9686	0.704	496.8748	0.694	497.9171	0.723
490.9753	0.701	496.8806	0.697	497.9225	0.712
490.9810	0.704	496.8866	0.694	497.9279	0.715
490.9884	0.707	496.8922	0.694	497.9331	0.703
		496.8981	0.706		

HD 59527", corrected for the effect of atmospheric extinction, are given in Table 1. The extinction coefficient was derived from observations of the comparison star by means of the Bouguer method. A mean value, equal to

0.25 per air mass, was used in the reductions. The differential extinction corrections never exceeded 0.002 mag.

3. Discussion

3.1. Evidence for a beat phenomenon

The least-squares (LS) spectrum (Lomb 1976) of the differential magnitudes of Table 1 shows substantial amplitudes in the frequency range from 0 to 8 c/d (cycles per day), the highest peaks occurring between about 3 and 5.5 c/d. The LS spectrum over the latter frequency range is displayed in the upper panel of Fig. 1. Lower panel of this figure shows the spectral window function in the form of the LS spectrum of a 4.2 c/d sine-curve, sampled at the epochs of observations. At first sight the two spectra seem identical.

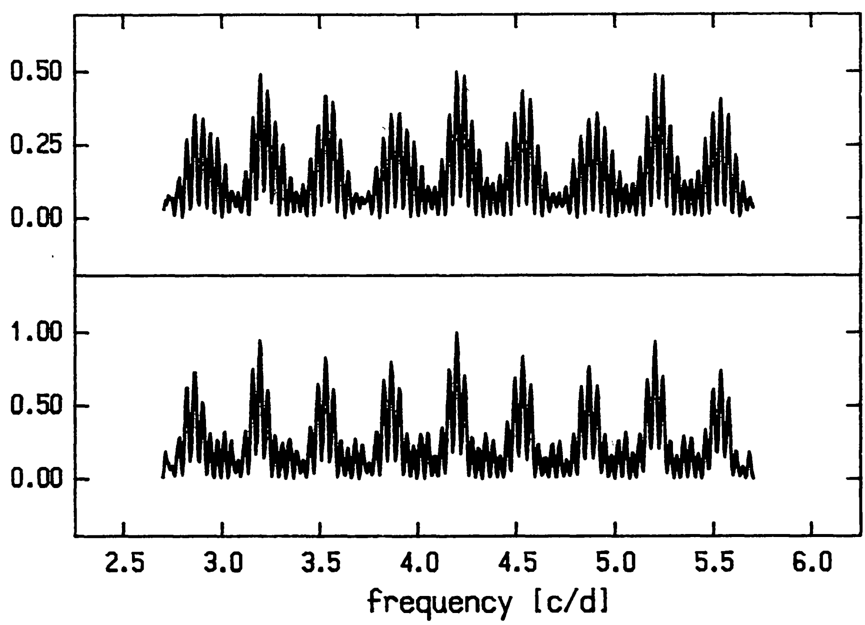

Fig. 1. The least-squares spectrum of the differential *B* magnitudes "HD 59864 minus HD 59527" (upper panel) and of the 4.2 c/d sine-curve, sampled at the epochs of observations (lower panel). Ordinate is the normalized spectral function, as defined by Lomb (1976). Note the difference in scale between the upper and lower panel.

In either case one can see a series of bands, split into narrow lines. The width and separation of the latter are both approximately equal to the resolution of the spectrum, amounting to about $1/\Delta t$, where $\Delta t = 28$ days is the time interval covered by observations. There is, however, a difference: while in the window spectrum there are three strong lines in each band, in the data spectrum there are four. As can be easily verified by numerical experiment, a spectrum of this sort would result if the light variation consisted of two sine-curve components having frequencies that differ by about

$$\Delta f = n \pm x/\Delta t \tag{2}$$

where n is a small whole number and x is such that the spectral window patterns corresponding to the two components are just resolved.

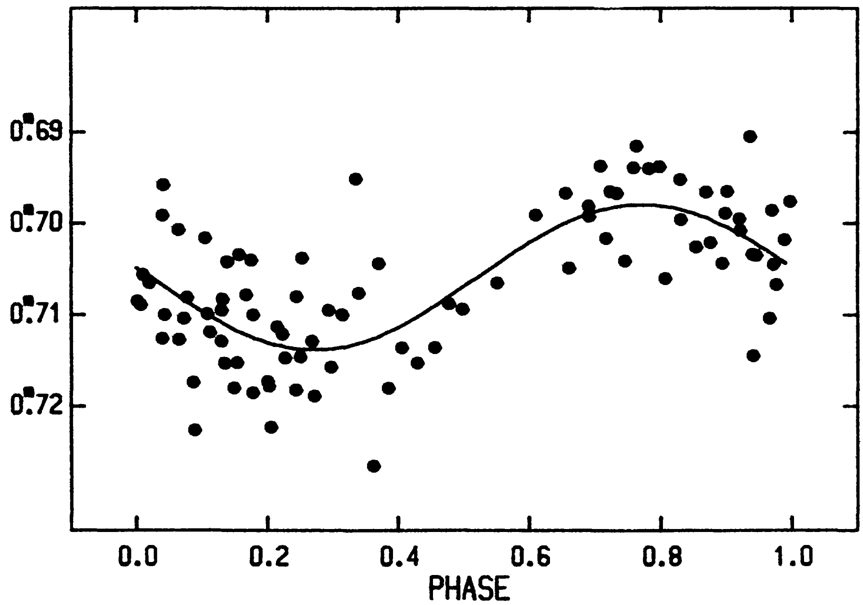

Fig. 2. The differential B magnitudes, "HD 59864 minus HD 59527", plotted as a function of phase of the 4.201 c/d frequency. The epoch of phase zero is JD 2446000. The best-fitting sine-curve of this frequency is also shown.

The most likely value of n is, of course, zero. In such a case the two components combine to produce beats. Thus, a beat phenomenon is probably responsible for the additional lines in the LS spectrum of HD 59864.

3.2. The strongest sine-curve component

The highest peaks in the data LS spectrum (upper panel of Fig. 1), all having very nearly the same height, occur at 3.198, 4.201, 5.205, 4.240, and 5.244 c/d. The first three peaks form a series of 1 cycle/sidereal day aliases, while the fourth and the fifth are $1/\Delta t$ side-lobes of the second and the third. One of the above-mentioned five frequencies must be approximately equal to the frequency of the strongest component in the light variation of HD 59864. For the sake of illustration, Fig. 2 shows the data plotted as a function of phase of the 4.201 c/d frequency. Also shown in Fig. 2 is the sine-curve of this frequency, fitted to the data by the method of least squares. Its amplitude (half-range) amounts to 0.0079 ± 0.0009 mag..

3.3. The second strongest component

Standard deviation of the fit shown in Fig. 2 is equal to 0.0057 mag. The other four best values of the frequency yield the same standard deviations.

As in the case of HD 59594 (Jerzykiewicz and Sterken 1990), analysis of phase diagrams, plotted for each night separately, led us to the conclusion that this relatively large value is due mainly to observational scatter caused by inadequate weather. We nevertheless made the following attempt to derive the sine-curve component responsible for the beat phenomenon discussed in Paragraph 3.1.

Using the abovementioned five values of the frequency we prewhitened the data and computed LS spectra of the residuals. In all five spectra there was a number of peaks of about the same height. In order to narrow down the number of possibilities, we postulated that the beat period of HR 59864 is of the order of ten days, as this value is typical of β Cephei stars with beat phenomenon. This eliminated the frequency of 3.198 c/d, because there was no peak above the noise level in the vicinity of 3 c/d in the corresponding LS spectrum. (Another argument against this frequency is that it corresponds to a period too long for a β Cephei star.) For each of the remaining four primary frequencies, a secondary frequency, consistent with our postulate, could be unambiguously identified. In order of increasing primary frequency, the secondary frequencies were 4.318, 4.123, 5.325 and 5.123 c/d. Thus, for the first two pairs of frequencies the beat period is equal to 8.6 days, and for the remaining two pairs, to 8.3 days.

Regardless of which pair of frequencies is used in a two sine-curve least squares fit to the data, the standard deviation amounts to 0.0054 mag. The four amplitudes of the primary components cover a range from 0.0071 mag. to 0.0077 mag., and amplitudes of the secondary components, a range from 0.0031 mag. to 0.0036 mag. Since the mean error of the amplitudes is equal to 0.0009 mag., these ranges are insignificant. Thus, all four pairs of fre quencies represent the data equally well.,

Standard deviation of the two-component fits is almost as large as the standard deviation of the single component fits mentioned at the beginning of this paragraph. This is in agreement with our conclusion that scatter in Fig. 2 is due mainly to observational errors. Since, however, deviations from the sine curve in Fig. 2 have about the same amplitude as the sine curve itself, one should also consider the possibility that a spurious periodicity, instead of a beat phenomenon, is responsible for the difference between the data and window spectrum patterns, discussed in Paragraph 3.1. Fortu nately, this possibility can be eliminated because: (1) in the LS spectra of the residuals, mentioned earlier in this paragraph, the highest peaks occur in bands consisting of three strong lines, that is, they show the same pattern as the window spectrum, and (2) the LS spectrum of HD 59594, derived from observations which were obtained simultaneously with the present ones, also shows the same pattern of three strong lines per band (see Jerzykiewicz and Sterken 1990, Fig. 1).

4. Summary

From photoelectric observations, carried out on five nights in February and March 1986, we find HD 59864 to be a β Cephei type variable. Frequency analysis of the data indicates that a beat phenomenon is present in the light variation and yields five possible values of the frequency of the strongest sine curve component. This number can be reduced to four if the beat period is assumed to be of the order of ten days. Moreover, for each of these four values, a frequency of the second strongest component can be unambiguously derived.

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REFERENCES

Jerzykiewicz, M. and Sterken, C. 1979, *I. A. U. Colloquium No. 46, Changing Trends in Var. Star Research*, ed. by F. M. Bateson, J. Smak, and I. H. Urch (Univ. Waikato, Hamilton, N. Z.), p. 474.

Jerzykiewicz, M. and Sterken, C. 1990, *Acta Astr.*, **40**, 117, this issue.

Kilkenny, D. 1978, *Mon. Not. R. astr. Soc.*, **182**, 629.

Kilkenny, D. 1981, *ibid.*, **194**, 927.

Lomb, N. R. 1976, *Astrophys. Space Sci.*, **39**, 447.

Sterken, C. and Jerzykiewicz, M. 1983, *Acta Astr.*, **33**, 89.