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HD 59594: a New δ Scuti Variable Star [1]

by

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ABSTRACT

Photoelectric observations of HD 59594 are reported. It is shown that the star is a δ Scuti variable with at least two short-period components present in its light variation. Periods and amplitudes of the two strongest components are derived.

1. Introduction

HD 59594 was used by us as a comparison star in a program of differential photoelectric photometry of HD 59864. The latter star has been selected for observing because in the colour- magnitude diagram it falls in the region occupied by β Cephei variables. Observations of HD 59864, which was indeed found to show β Cephei-type light variations, are reported elsewhere (Sterken and Jerzykiewicz 1990). In the present paper we deal with HD 59594.

2. Equipment and observations

The observations were obtained by C.S. on five nights in February and March 1986 at the Mt. John Observatory and on two nights in November 1986 at the ESO. At the Mt. John Observatory the equipment consisted

[1] Based on observations obtained at the Mt. John Observatory, Lake Tekapo, New Zealand, and at the European Southern Observatory, La Silla, Chile.
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of the Optical Craftsman 60-cm reflec- ting telescope and a conventional photoelectric photometer, containing a standard B filter and a blue-sensitive photo- multiplier tube. At ESO the observations were obtained with the Danish 50-cm telescope and the *uvby* photometer. In both cases pulse-counting electronics was used. The measurements, each consisting of two to four 5 or 10-second integrations, were taken in the following order:

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

where $C1$ = HD 59594, P = HD 59864, and $C2$ = HD 59527.

The results, in the form of magnitude differences "HD 59594 minus HD 59527", corrected for the effect of differential atmospheric extinction, are given in Tables 1 and 2. The ex- tinction corrections never exceeded 0.005 mag.; in B, b, and y they were always smaller than 0.002 mag.

Table 1

The B filter differential magnitudes of HD 59594 obtained at the Mt. John Observatory

HJD	Δm	HJD	Δm	HJD	Δm
2446000+		2446000+		2446000+	
469.9377	0.697	490.9926	0.734	496.8965	0.712
469.9536	0.704	491.0015	0.720	496.9022	0.713
469.9634	0.718	491.0087	0.713	496.9076	0.708
469.9734	0.720	491.0163	0.722	496.9131	0.712
469.9819	0.720	491.0242	0.713	496.9184	0.710
469.9902	0.701	491.0327	0.718	496.9239	0.707
469.9995	0.702	491.0424	0.727	496.9287	0.712
470.0072	0.710	491.0513	0.717	496.9346	0.734
470.0154	0.726			496.9398	0.719
470.0243	0.719	493.8791	0.718	496.9452	0.719
470.0319	0.713	493.8837	0.714	496.9523	0.702
470.0409	0.695	493.8899	0.707	496.9578	0.703
470.0489	0.698	493.8962	0.714	496.9631	0.706
470.0567	0.716	493.9024	0.715	496.9683	0.709
470.0656	0.722	493.9079	0.716	496.9738	0.710
470.0781	0.730	493.9135	0.727	496.9791	0.716
470.0869	0.709	493.9182	0.730	496.9848	0.720
470.0956	0.696	493.9236	0.723	496.9902	0.715
470.1045	0.726	493.9295	0.717	496.9957	0.719
470.1169	0.734	493.9347	0.718	497.0008	0.716
470.1268	0.704	493.9400	0.711	497.0065	0.711
470.1356	0.709	493.9452	0.704		
470.1460	0.703	493.9506	0.708	497.8795	0.716
		493.9572	0.725	497.8866	0.735
490.9102	0.703	493.9625	0.728	497.8940	0.727
490.9179	0.703	493.9670	0.730	497.8994	0.707
490.9247	0.708	493.9732	0.723	497.9047	0.708
490.9312	0.711			497.9103	0.706
490.9665	0.711	496.8618	0.705	497.9158	0.711
490.9731	0.706	496.8791	0.715	497.9208	0.708
490.9796	0.703	496.8850	0.730	497.9266	0.711
490.9868	0.724	496.8908	0.715	497.9316	0.709

3. Discussion

3.1. The strongest sine-curve component

The least-squares (LS) spectrum (Lomb 1976) of the Mt. John Observatory data is shown in the upper panel of Fig. 1 in the frequency range where it has large amplitudes. Lower panel of the figure shows the spectral window function in the form of the LS spectrum of a 20 c/d (cycle per day) sine-curve, sampled at the epochs of observations. The highest peak in the

Table 2

The *uvby* differential magnitudes of HD 59594, obtained at the European Southern Observatory

HJD	Δu	Δv	Δb	Δy
2446000+				
759.8203	1.419	0.805	0.557	0.396
759.8271	1.424	0.810	0.561	0.399
759.8331	1.432	0.818	0.570	0.407
759.8391	1.436	0.823	0.573	0.411
760.7301	1.417	0.801	0.556	0.393
760.7362	1.424	0.810	0.564	0.399
760.7419	1.428	0.823	0.572	0.408
760.7477	1.430	0.826	0.573	0.410

data LS spectrum occurs at 19.976 c/d, but its 1 cycle/sidereal day alias at 20.8805 c/d is almost as high. The period of HD 59594 cannot thus be derived unambiguously from the Mt. John Observatory data. It is equal to 0.050312 or 0.047892 day, the latter value corresponding to the alias peak. The ESO data can also be represented equally well by either period (see below).

In any case, the period is close to 0.05 day. This period, together with the star's spectral type of A2, make HD 59594 a typical representative of the δ Scuti class of variables. Fig. 2 shows the Mt. John Observatory differential B magnitudes, plotted as a function of phase of the 0.050312 day period. Zero phase corresponds to J.D. 2446000. The sine-curve of this period (solid line in Fig. 2), fitted to the data by the method of least squares, has an amplitude (half range) of 0.0095 ± 10.0010 mag. and reduces the original standard deviation of 0.0094 day to 0.0065 day. The amplitude and standard deviation obtained with the alias period of 0.047982 day are practically the same: they differ from the above-mentioned values by less then 0.0001 mag. The 0.050312 day sine-curve fit to the ESO b data is shown in Fig. 3. The amplitude amounts to 0.0097 ± 10.0012 mag. Because

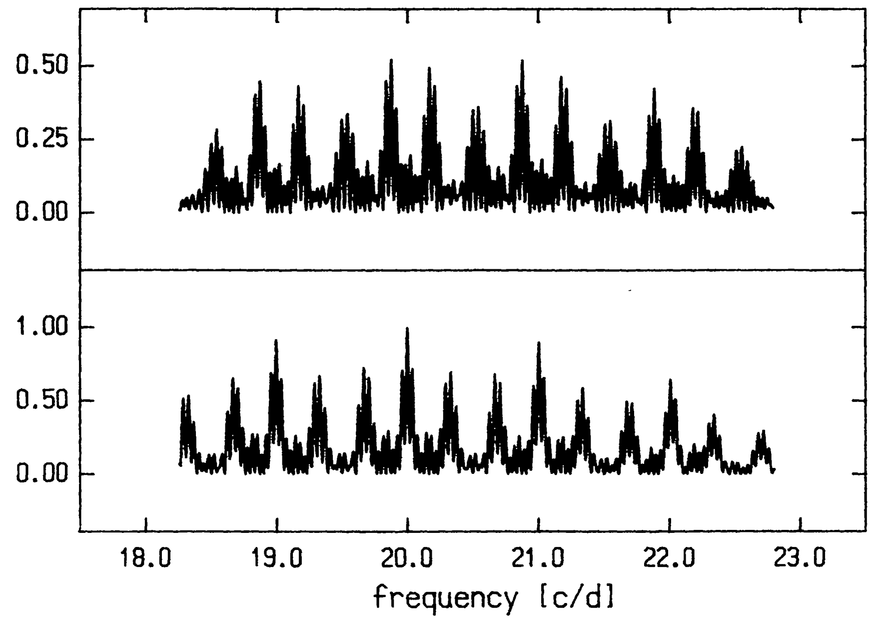

Fig. 1. The least-squares spectrum of the differential B magnitudes "HD 59594 minus HD 59527" (upper panel) and of the 20 c/d sine-curve, sampled at the epochs of observations (lower panel). Ordinate is the normalized spectral function, as defined by Lomb (1976). Note the difference in scale between the upper and lower panels.

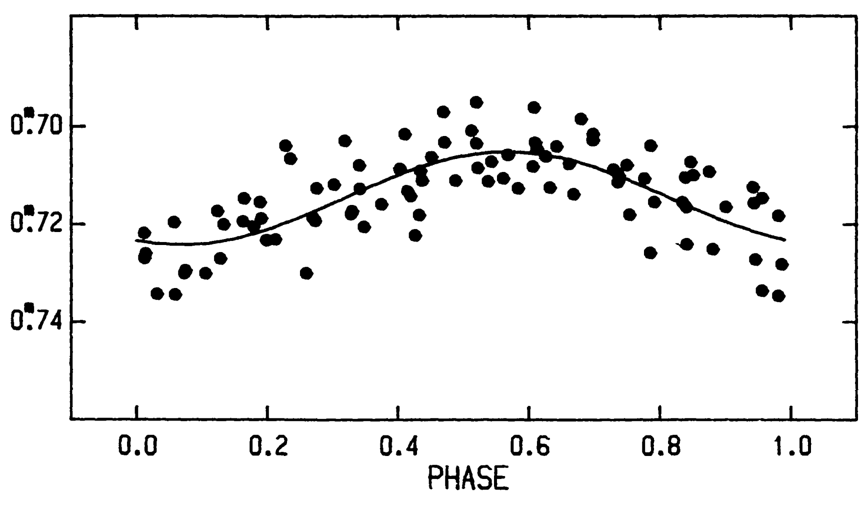

Fig. 2. The differential B magnitudes, "HD 59594 minus HD 59527", plotted as a function of phase of the 0.050312 day period. The epoch of phase zero is JD 2446470. The best-fitting sine-curve of this period is also shown.

of the small number of data points and the secondary variation discussed in the next paragraph, the very good agreement with the value obtained above may be somewhat fortuitous. The am- plitudes in u, v, and y are equal to $0.0085 \pm 0.0025, 0.0122 \pm 0.0015$, and 0.0091 ± 0.0013 mag., respectively. Fits with the alias period of 0.047982 day have the same amplitudes. Thus, ESO obser- vations, although confirming the δ Scuti nature of the light variation, cannot help to decide which of the two periods is the correct one. Furthermore, the 290-day gap between the ESO and Mt. John Observatory runs leads to ambiguities in counting the elapsed cycles, so that the ESO data cannot be used to improve the periods.

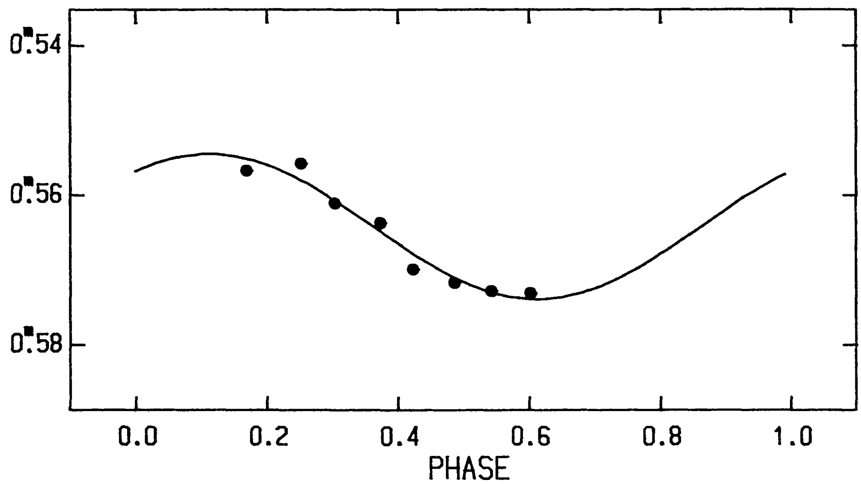

Fig. 3. The same as Fig. 2 but for differential b magnitudes. The epoch of phase zero is JD 2446760.

3.2. The secondary component

As we mentioned in the preceding paragraph, fitting a sine-curve with a period of either 0.050312 or 0.047892 day reduces the original standard deviation of the Mt. John Observatory data to 0.0065 mag. This relatively large value needs accounting for. Multiperiodicity, common among low amplitude δ Scuti stars, comes to mind as the most likely explanation. However, the 0.05 day sine-curve fits to observations on individual nights have standard deviations ranging from 0.0034 mag. on JD 2446493 to 0.0078 mag. on JD 2446497. The mean value of the nightly standard deviations amounts to 0.0060 mag. Thus, most of the scatter seen in Fig. 1 is probably due to the fact that a large fraction of the data was obtained on nights of inadequate photometric quality.

However, the LS spectrum of residuals from the 0.050312 day sine-curve fit to all Mt. John Observatory data is not that of pure white noise. It shows relatively high amplitudes in the frequency range from 30 to 34 c/d, the highest peak occuring at 31.610 c/d = 1/(0.031636 day). In the case of residuals from the sine-curve fit with the alias period of 0.047892 day, the highest peak occurs at exactly the same frequency. In both cases, however, the highest peak is flanked by 1 cycle/sidereal day aliases of nearly the same height.

Amplitudes A_i and epochs of maximum light JD_{max} of a two-component sine-curve fit to the Mt. John Observatory data, computed by the method

Table 3

Parameters of a two-component sine-curve fit to the Mt. John Observatory differential B magnitudes Number of observations = 92, Standard deviation = 0.0058 mag., Mean = 0.7147±0.0006

i	P_i	A_i	JD_{max} - 2446000
1	$0.^d050312$	$0.^m0099 \pm 0.^m0009$	$470.^d0436 \pm 0.^d0007$
2	$0.^d031636$	$0.^m0043 \pm 0.^m0009$	$470.^d0315 \pm 0.^d0010$

of least squares with P_1 and P_2 assumed equal to 0.050312 and 0.031636 day, respectively, are given in Table 3. As can be seen from the table, the amplitude of the secondary component is certainly significant. Parameters of a fit with P_1 equal to 0.047892 day, instead of 0.050312 day, would be very nearly the same. Thus, in spite of their rather mediocre accuracy, Mt. John Observatory data indicate that at least two sinusoidal components are present in the light variation of HD 59594. Table 3 amplitudes of the two strongest components are probably correct to within the quoted mean errors. The periods , on the other hand, may differ from the true ones because of the above-mentioned ±11 cycle/sidereal day ambiguities.

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