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Three known and twenty-two new variable stars of early spectral type*

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Abstract. — Photoelectric photometry is reported of three known and 22 new variables, all brighter than $V = 7\overset{m}{.}5$. The three known ones are: the ellipsoidal variable 42 (V467) Per, the β Cep-type star HR 6684 = V2052 Oph, and the eclipsing variable HR 8854 = V649 Cas. The new variable stars are listed in Table 4. They include two β Cep candidates, one eclipsing and three ellipsoidal variables, a "mid-B" variable, an α^2 CVn variable, and two λ Eri stars. The twelve remaining new variables could not be classified because of insufficient data. The λ Eri variables found in the present investigation, together with some examples from the literature, indicate that rotational modulation occurs not only in Be, but also in normal B stars.

Key words: photometry — stars: individual — stars: variable — stars: early-type

1. Introduction

In 1972 and 1973, the author carried out an observing program of testing early B stars for small-amplitude light variability, characteristic of the β Cep-type stars. Program stars were selected from among the Bright Star Catalogue objects having MK classes such as those of known β Cep variables.

The program was started in the spring of 1972 at the Mauna Kea Observatory, but most observations were obtained at Lowell Observatory in the period from July 1972 to November 1973. One of the first stars to be observed, HR 6684, turned out to be a new β Cep variable. Unfortunately, among several variables subsequently discovered in the course of the program, only two rather questionable β Cep candidates were found. This near failure of the program may have been caused by the circumstance that a number of stars originally intented to be observed were dropped because of exceptionally poor weather prevailing over Northern Arizona in the last quarter of 1972. In addition, due to the limitations of telescope time, most stars were observed only once or twice per night.

The discovery observations of HR 6684 and a brief discussion of its light variability was published long ago (Jerzykiewicz 1972). The present paper contains an account of the remaining results of the program.

2. Equipment, observations and reductions

The observations reported in this paper were obtained with a single channel photometer, mounted in the Cassegrain focus of the Lowell Observatory's 42-inch telescope. The photometer contained an EMI 6256S photomultiplier tube, refrigerated at −20°C, and a set of standard *uvby* filters. The electronics consisted of LeCroy Research System pulse-counting modules, Model 133 amplifier and Model 128D discriminator. All measurements were recorded by a computerized data-acquisition system developed by Albrecht et al. (1971).

The measurements were taken in the following order:

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

where P denotes a program star, C1 and C2, comparison stars, and each symbol represents a 10-second integration. The comparison stars were selected from the HD catalogue according to the well-known rules of similarity of spectral type and brightness. Care was taken to exclude emission line objects and known variable stars. In order to meet these requirements, it was sometimes necessary to use comparison stars up to about five degrees apart. Even so, the choice was occasionally rather poor, especially with regard to spectral type.

The program and comparison stars are listed in Table 1. The stars are arranged in sets of three, as they were observed. In each set the order is P, C1, C2. In two cases, two program stars appear in the same set, so that one of them serves as a comparison star for the other; these cases are indicated by asterisks in column 1. The MK classes

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* Based on observations obtained at Lowell Observatory

(column 3) are from Lesh (1968), Kennedy & Buscombe (1974), Jaschek et al. (1964), and Hoffleit et al. (1983). If no MK classification could be found in the literature, the HD spectral type is given. The last column of Table 1 contains variability classes, introduced and explained in the next section.

Table 2 is an additional list of program and comparison stars. It has the same format as Table 1. The first two program stars in Table 2, HR 8706 and HR 8758, were originally used as comparison stars and found variable in light. Although their MK classification implies that they are rather unlikely to show β Cep-type variations, it seemed worthwhile to try to determine the character of their variability. For the other two program stars appearing in Table 2, the comparison stars were changed in the course of the program because the original ones turned out to be variable. Unfortunately, the second choice was not much better than the first.

Table 2. The program and comparison stars. Additional list

HD	Name or HR	Sp	V	Class
216538	8706	B7 III-IV	$6\overset{\mathrm{m}}{.}3$	var
216831	8723	B7 III	5.7	cst
217101	8733	B2 IV-V	6.2	cst
217543	8758	B3 Vp	6.5	var
216831	8723	B7 III	5.7	cst
217101	8733	B2 IV-V	6.2	cst
218440	8803	B2.5 IV	6.4	var*-
217943	8777	B2 V	6.7	var
218537	8808	B3 V	6.3	var*+
219634	8854	B0 Vn	6.5	var
218440	8803	B2.5 IV	6.4	var*-
218537	8808	B3 V	6.3	var*+

Depending on the photometric quality of a night, an observation consisted of two or three sequences (1) per set. This required about twelve to twenty minutes of observing time. A given set was always observed with the same filter, either b or y. In principle, the u, v, or b filter should be preferred over y because the light amplitudes of the β Cep-type stars increase with decreasing wavelength. However, the y filter observations are least affected by the atmospheric extinction related errors. In addition, the shorter wavelength interference filters tend to be somewhat unstable. Consequently, the y filter was used, as a rule, if comparison stars were far apart or had widely different spectral types. The brightest program stars were also observed in y in order to reduce the count overlap errors. In the remaining cases, the observations were taken with the b filter. The count overlap errors for the brightest stars were further reduced by means of limiting the flux with the telescope shutter. This was possible because in the 42-inch telescope the shutter could be used as an iris diaphragm. The count overlap correction was carefully determined and applied to all measurements.

Table 1. The program and comparison stars

HD	Name or HR	Sp	V	Class
3360*	ζ Cas	B2 IV	$3\overset{\mathrm{m}}{.}7$	cst
3240	144	B7 III	5.1	cst
3901*	ξ Cas	B2.5 V	4.8	cst
22951	40 Per	B1 IV	5.0	cst
21856	1074	B1 V	5.9	cst
23848	42 Per	A3 V	5.1	var
23625	1163	B2.5 V	6.6	var?+
23478	--	B3 IV	6.7	var
24190	--	B2 Vn	7.4	var?+
27192*	1333	B1.5 IV	5.6	var
27084	1330	A7 V	5.4	cst?-
28446*	1 Cam	B0 IIIn	5.8	cst?+
37232	1913	B2 IV-V	6.1	cst:
36881	1883	B9 IIIp	5.6	cst:
37320	1920	B8 III	5.9	cst:
37367	1924	B2 IV-V	6.0	var
37098	1902	B9 IV-V	5.8	cst:
37519	1938	B9.5 III-IV	6.0	cst:
48434	2479	B0 III	5.9	var
47431	2441	B6 V	6.6	cst:
48099	2467	O 5.5	6.4	cst:
52559	2633	B2 IV-V	6.6	var
52479	2629	A3 Vs	6.6	cst?
53202	--	B9	7.4	cst?
87015	3952	B2.5 IV	5.7	var
86516	--	Am	6.7	cst?
88737	4012	F5	6.0	cst?
142096	λ Lib	B2.5 V	5.0	var
142883	5934	B3 V	5.8	var?
142805	--	B9 V	7.1	var?
163472	6684	B2 IV-V	5.8	var
163624	6689	A3 V	6.0	var?
163792	--	A0	6.7	var?
164432	6719	B2 IV	6.3	var?
164257	--	A0	6.7	var
163641	6690	B9 III	6.3	var?-
166182	102 Her	B2 IV	4.4	cst?
164852	96 Her	B3 IV	5.3	var
166230	101 Her	A8 III	5.1	cst?
170740	6946	B2 IV-V	5.7	var?
169033	6881	B8 IV-V	5.7	cst?
173320	--	B8	7.0	cst?
176819	7200	B2 IV-V	6.7	cst:
176818	--	B1 V	7.0	cst:
176803	--	B8	7.2	cst:
177003	7210	B2.5 IV	5.4	var?
175824	7154	F5	5.8	cst
178207	51 Dra	A0 Vn	5.4	cst
181409	7335	B2 IV	6.6	var?
181492	--	B3 V	6.8	var
180844	--	B5	7.0	var?
195556	ω^1 Cyg	B2.5 IV	5.0	var
196178	7870	B9p Si	5.8	var?+
195965	--	B0 V	7.0	var?-
197770	7940	B2 III	6.3	var
198679	--	B9	6.7	var?
197618	--	A3	6.9	var?
199661	8029	B2.5 IV	6.2	var
200575	--	B8 V	6.7	var?
198793	--	B8	7.1	var?
201819	8105	B0.5 IVn	6.5	var
202126	--	A2	6.7	cst?
202240	8120	F0 III	6.0	cst?
217101	8733	B2 IV-V	6.2	cst
216538	8706	B7 III-IV	6.3	var
217543	8758	B3 Vp	6.5	var
218440	8803	B2.5 IV	6.4	var*-
217943	8777	B2 V	6.7	var
219634	8854	B0 Vn	6.5	var
223128	9005	B2 IV	6.0	cst?
223274	9013	A1 Vn	5.0	cst?
223358	9017	A0p	6.4	var?

The reductions were carried out in the usual manner. Seasonal mean atmospheric extinction coefficients were used in order to derive the differential extinction corrections. For each observation the final results were the three differential magnitudes, "P minus C1", "C2 minus P", and "C1 minus C2", and the corresponding heliocentric Julian dates. These results have been deposited in the IAU Archives of Unpublished Observations of Variables Stars, file 245.

3. Standard deviations and an approximate assessment of light variability

After observations had been reduced, the next step consisted in calculating standard deviations for each series of differential magnitudes. These standard deviations are given in Table 3, in the second, third and fourth column for the differential magnitudes "P minus C1", "C2 minus P", and "C1 minus C2", respectively. Program stars are identified in the first column by their HD numbers. Fifth column contains the number of nights, n, on which the stars were observed, and column six, the total number of observations, N. The filter is indicated in the last column. The last four lines of Table 3 were obtained from the differential magnitudes of the program and comparison stars listed in Table 2.

Table 3. Standard deviations (in mmag)

HD of P	P - C1	C2 - P	C1 - C2	n	N	F
3360	2.2	2.5	2.2	16	21	*y*
22951	2.1	14.7	14.5	31	55	*y*
23625	5.7	3.5	6.6	37	49	*b*
27192	3.9	5.2	2.9	27	34	*y*
37232	2.4	2.9	2.3	9	12	*y*
37367	13.0	12.6	2.1	13	17	*y*
48434	10.0	9.4	1.6	8	19	*b*
52559	7.0	7.4	2.6	11	20	*b*
87015	5.3	5.6	2.7	15	21	*y*
142096	5.3	5.5	4.1	9	19	*y*
163472	11.6	12.2	3.7	14	39	*b*
164432	5.9	3.9	5.1	26	29	*y*
166182	6.8	2.5	6.1	25	32	*y*
170740	4.3	4.1	2.5	17	21	*y*
176819	2.4	3.1	2.5	14	17	*b*
177003	3.2	3.9	1.9	30	34	*y*
181409	6.1	3.2	5.9	19	20	*b*
195556	7.7	7.6	3.3	33	47	*b*
197770	10.9	10.8	3.1	41	43	*b*
199661	6.2	5.1	3.2	32	40	*b*
201819	4.5	4.6	2.5	23	33	*y*
217101	7.5	6.0	7.3	11	11	*b*
218440	6.0	17.2	15.8	10	10	*b*
223128	2.6	3.6	3.2	20	25	*y*
216538	5.5	5.7	1.7	18	26	*b*
217543	6.2	6.3	1.8	29	36	*b*
218440	6.5	4.8	6.9	28	29	*b*
219634	27.5	27.0	5.1	18	22	*b*

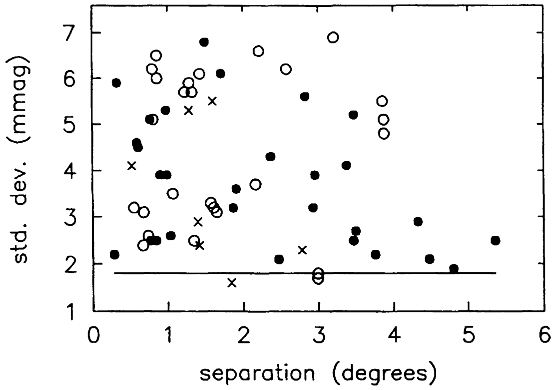

Fig. 1. Standard deviations, in mmag, of the differential magnitudes. The abscissae are angular separations in degrees. The filled and open circles represent standard deviations of the y and b differential magnitudes, respectively, obtained on 10 or more nights, while crosses, those from y or b observations obtained on less than 10 nights. The horizontal straight line at 1.8 mmag is the lower limit of the standard deviations discussed in the text

Standard deviations from Table 3 are used as ordinates in Fig. 1. The abscissae are angular separations, in degrees, between the stars involved in the corresponding differential magnitudes. Standard deviations greater than 7.0 mmag are not shown.

Fig. 1 can be used to derive the lower limit of the standard deviations. Giving more weight to standard deviations obtained from observations taken on ten or more nights, we estimate this lower limit to be equal to 1.8 mmag, the same for y and b. Surprisingly, it is also independent of the separation over the entire range covered by the present data, that is, up to about 5 degrees. The lower limit of the standard deviations is represented in Fig. 1 by the horizontal straight line.

Aside from stellar light-variability, the main factors that can make standard deviation of a differential magnitude exceed its lower limit are the following: (1) poor photometric quality of some nights, (2) observing through large air masses, (3) instrumental problems. In our case, the last factor can be omitted because instrumental problems caused gross errors that were easily recognized as such and eliminated. The second factor was seldom important because very few stars were ever observed through air masses greater than 1.3. The most serious was the first factor. As we mentioned in the preceding section, an attempt was made to compensate for poorer photometric quality of some nights by taking more integrations. Occasionally, however, the compensation may have been inadequate. Since different series of observations were, of course, affected in different degree, the same value of the standard deviation may indicate different amounts of stellar light-variability. If all stars observed in the present program were constant in light, the standard deviations would have an upper limit set by observations obtained on the worst nights. This upper limit is probably equal to about 4.5 mmag, because at this ordinate there is a minimum in the distribution of standard deviations in Fig. 1. Furthermore, a local maximum can be seen in the distribution of ordinates in this figure around 2.5 mmag. This value must therefore be close to the mode of the frequency distribution generated by the observational errors alone.

The above discussion can be summarized as follows. Standard deviations greater than 4.5 mmag indicate light-variability. On the other hand, a standard deviation smaller than 2.5 mmag is probably dominated by observational errors. Values falling between these two limits correspond to intermediate cases: observational errors alone could make some standard deviations as large as 4.5 mmag, whereas a light variation may be responsible for a part of a 2.5 mmag standard deviation if the errors were at their minimum.

These results form the basis of the following variability classification. A star is regarded as constant in light if at least one series of differential magnitudes in which it was involved has standard deviation smaller than 2.5 mmag. Such stars are denoted by *cst* or *cst*: in the last columns of Tables 1 and 2; the second notation, appearing only in Table 1, is used when the number of observations, N, is smaller than 20. Stars responsible for standard deviations greater than 4.5 mmag are denoted *var*. An asterisk appears after *var* in the few cases when it was not clear which star caused the standard deviation to exceed the limit of 4.5 mmag. The remaining stars are classified as *cst*? if standard deviations of their differential magnitudes are smaller than 3.0 mmag, or as *var*? otherwise. Finally, a plus sign after *cst*?, *var*? or *var** denotes stars for which variability is confirmed by a more detailed analysis in the next section, while a minus sign denotes the opposite, that is, stars found constant in the next section.

4. The individual stars

In some cases the data were sufficient to derive periods. Unless stated otherwise, we derived periods using the method of least-squares (LS) frequency analysis. In this method, a power spectrum is obtained by fitting sine curves to the data by least-squares and plotting the normalized reduction in the sum of squares of residuals, $p(f)$, as a function of frequency. Details of the method can be found in Lomb (1976).

4.1. *42 Per = V467 Per*

This star was used as C2 for 40 Per = HD 22951. Fortunately, 40 Per and the other comparison star, HR 1074, both turned out to be constant. Differential magnitudes VAR = "42 Per minus the mean of 40 Per and HR 1074" could therefore be used to investigate the variability of 42 Per.

The highest peak in the power spectrum of VAR occurred at 1.133 c/d. However, when the data were plotted as a function of phase of the corresponding period of $0\overset{\mathrm{d}}{.}8826$, it became apparent that the correct period must be close to twice this value. That this is indeed the case can be seen from Fig. 2, where VAR are plotted as a function of phase of the period equal to $1\overset{\mathrm{d}}{.}7654$. The star is clearly an ellipsoidal variable, rather similar to the prototype of the class, *b* Per (Stebbins 1923).

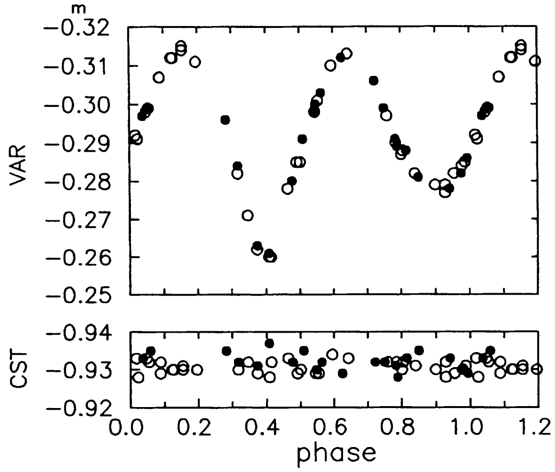

Fig. 2. Differential magnitudes VAR = "42 Per minus the mean of 40 Per and HR 1074" (top) and CST = "40 Per minus HR 1074" (bottom), phased with the period of $1\overset{\mathrm{d}}{.}7654$. The epoch of phase zero is HJD 2441600. Filled circles represent observations obtained between November 1972 and February 1973, while open circles, those obtained between August and October 1973

The orbital period of $1\overset{\mathrm{d}}{.}765346$ was independently derived by Morbey and Brosterhus (1974) from published radial-velocity data. A light-curve analysis of the system was carried out by Martin et al. (1990a).

4.2. *HD 23478, HD 24190, and HR 1163*

HD 23478 was C1 for HR 1163 = HD 23625. As can be seen from the standard deviations in Table 3, the star is certainly variable. In addition, the standard deviations indicate that C2 = HD 24190 and P = HR 1163 may be slightly variable.

Fig. 3 shows "HD 23478 minus HR 1163", "HD 23478 minus HD 24190", and "HD 21490 minus HR 1163" power spectra. The first two spectra (top and middle) are dominated by peaks at 0.9525 c/d and their ±1 cycle per sidereal day (c/sd) aliases. HD 23478 must be responsible for these peaks because the third spectrum (bottom) has a different structure.

In Fig. 4, the differential magnitudes "HD 23478 minus HR 1163" are plotted as a function of phase of $1\overset{\mathrm{d}}{.}0499$, the period corresponding to 0.9525 c/d.

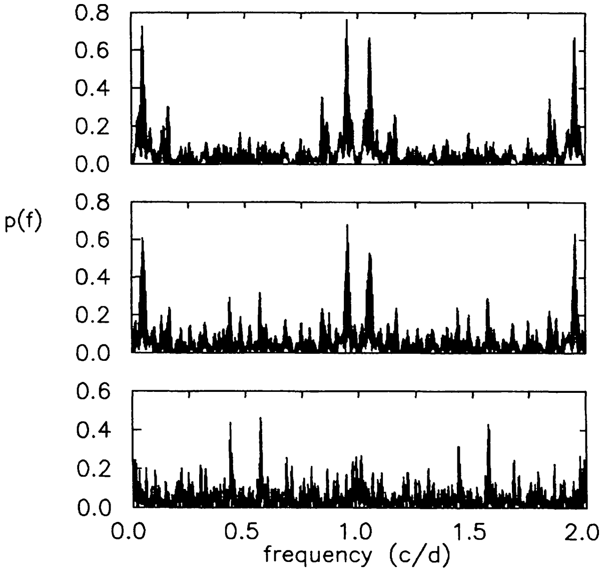

Fig. 3. The LS power spectra of the differential magnitudes "HD 23478 minus HR 1163" (top), "HD 23478 minus HD 24190" (middle), and "HD 24190 minus HR 1163" (bottom). The ordinate, $p(f)$, is the normalized reduction in the sum of squares of the residuals from a sine-curve fit with frequency f

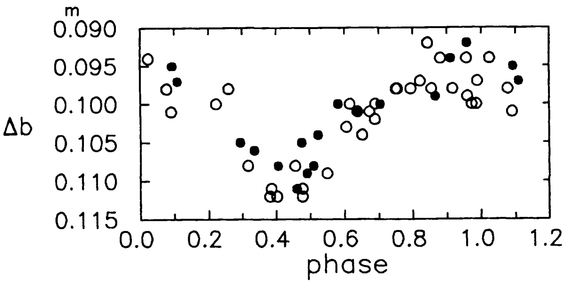

Fig. 4. Differential magnitudes Δb ="HD 23478 minus HR 1163", plotted as a function of phase of the period of $1^{d}.0499$. The epoch of phase zero is HJD 2441650. Filled circles represent observations obtained between November 1972 and February 1973, whereas open circles, those obtained between August and November 1973. Some scatter is due to HR 1163, which is also variable, but with a smaller amplitude than HD 23478 (see text)

This value of the photometric period suggests the following possibilities: (1) the star is an ellipsoidal variable, (2) it is a nonradial $g-$mode pulsator, or (3) its variability is caused by rotational modulation. We shall now discuss these possibilities in turn.

(1) In this case HD 24378 would be a binary with orbital period equal to twice the photometric one. Since the light-curve plotted with twice the photometric period has the shape of a double wave with equally deep minima, the eccentricity of the orbit must be close to zero. Therefore, in the lowest order approximation, certainly adequate in the present case, the amplitude of the light variation due to aspect changes of the tidally distorted component can be expressed by means of the following formula:

$$\delta m = 1.6 A_\lambda q (R/a)^3 \sin^2 i, \tag{2}$$

where A_λ is the photometric distortion parameter of Russell & Merrill (1952), R is the polar radius of the component, q is the mass ratio of the system, a is the diameter of the orbit, and i is the orbital inclination. Limits of applicability of this formula have been investigated by Ruciński (1969).

Eq. (2) can be used to derive i, because δm is known from the present observations, a can be obtained from Kepler's third law if the mass of HD 23478 is estimated from its spectral type of B3 IV, and R can also be estimated from the spectral type. Taking the mass and radius of a B3 IV star from Underhill (1982), Tables 2-11 and 2-12, and $A_\lambda = 0.8$ from Rucinski (1970), we get $29° < i < 90°$, where the lower bound is for an equal component binary, whereas the upper bound, for the secondary's mass equal to 1.2 solar masses. Using these values of i, we can predict the radial velocity ranges for comparison with the observed radial velocities of HD 23478. The predicted 2K range amounts to 210 km/s in the case of an equal component binary, and to 80 km/s in the other case.

The radial velocity of HD 23478 was measured by Plaskett & Pearce (1931) and by Blaauw & van Albada (1963). From five measurements, obtained between 1925 and 1928, Plaskett & Pearce (1931) concluded that the star is a spectroscopic binary with a range of 46 km/s. This was not confirmed by Blaauw & van Albada (1963), who observed HD 23478 on 14 nights in September 1954. Their measurements show a range of only 20 km/s. In any case, the observed velocity ranges are much smaller than the predicted ones. We therefore reject the possibility that HD 23478 is an ellipsoidal variable.

The referee has pointed out the following limitation of the above discussion. Since components of an ellipsoidal variable should be expected to corotate, the ellipsoidal variation may be accompanied by rotational modulation with a period equal to the orbital period. In such a case, the inclination estimated from Eq. (2) would be in error.

(2) Nonradial pulsations have been invoked in order to account for a number of phenomena observed in B stars, ranging from multiperiodicity of the β Cep variables to "moving bumps" in the line profiles of Be stars. In the present case, the length of the period implies a high overtone g mode. According to Waelkens & Rufener (1985), such modes are responsible for light variations they found in several mid-B stars. These "mid-B variables" have spectral types in the range from B2 to B8, and periods from about $1^{d}.2$ to $2^{d}.8$. Waelkens (1991) maintains that these variables are multiperiodic, with up to eight closely spaced frequencies. Of course, multiperiodicity provides the conclusive argument in favour of nonradial pulsations.

In order to find out whether HD 23478 is multiperiodic, we computed an LS power spectrum of the residuals, left after prewhitening the differential magnitudes "HD 23478 minus HR 1163" with the frequency 0.9525 c/d and its first harmonic. The highest peak occurred at 1.0267 c/d. The corresponding amplitude is equal to 2.7 ± 0.4 mmag. However, it will be shown below that HR 1163 is responsible for this peak. Prewhitening with the frequency of 1.0267 c/d leads to a noisy spectrum in which the highest peaks correspond to sine curves with amplitudes smaller than 1.5 mmag. There is thus no evidence in our data for multiperiodicity of HD 23478. However, this does not prove that the star is not a g-mode pulsator.

(3) Assuming the period of rotation of HD 23478 to be equal to the photometric one, and using the radius estimated from the spectral type, we obtain 240 km/s for the equatorial velocity of rotation. This is consistent with the observed projected rotational velocity of the star, equal to 198 km/s (Hoffleit et al. 1983), if the inclination of the rotation axis to the line of sight is 56°. Both values support the possibility of rotational modulation.

Another argument in favour of rotational modulation is the fact that the highest peak in the power spectrum of the above-mentioned Blaauw & van Albada (1963) radial velocity measurements occurs at 1.055 c/d, that is, close to −2 c/sd alias of 0.9225 c/d. It is thus not unlikely that the true period of the radial velocity variation of HD 23478 is equal to the photometric period.

Rotational modulation may be the cause of the light variations with periods in the range from 0.5 to 3 days, found by Balona and his co-workers in a number of Be stars (Balona et al. 1987; Cuypers et al. 1989; Balona et al. 1991). Balona (1990a, 1990b, 1991), who proposed to call these stars "λ Eri variables", has shown that their observed properties can be understood in terms of rotational modulation caused by active photospheric areas (that is, spots) and matter trapped above the photosphere by a magnetic field. From an observational point of view, the variability of HD 23478 cannot be distinguished from that of a λ Eri variable. We therefore propose that it be classified as such, despite its apparently normal spectrum.

We shall now consider HD 24190. The "HD 24190 minus HR 1163" power spectrum in Fig. 3 (bottom) is dominated by a peak at 0.5685 c/d and its ±1 c/sd aliases at 1.568 c/d and 0.434 c/d. These peaks can also be seen in the "HD 23478 minus HD 24190" spectrum (middle). Clearly, HD 24190 must be responsible. The corresponding periods are equal to $1^{\mathrm{d}}.759$, $0^{\mathrm{d}}.6378$, and $2^{\mathrm{d}}.304$, respectively. Fig. 5 shows the differential magnitudes "HD 24190 minus HR 1163", plotted as function of phase of the first period.

According to Blaauw & van Albada (1963), HD 24190 is a spectroscopic binary with a period equal $26^{\mathrm{d}}.1$. There is no relation between the latter period and the photometric period of $1^{\mathrm{d}}.759$ or its aliases.

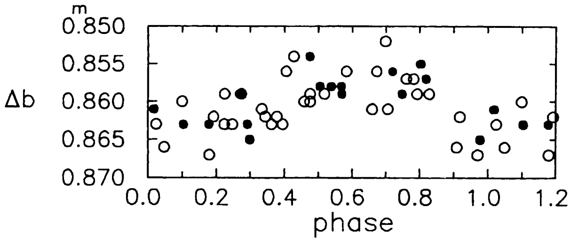

Fig. 5. Differential magnitudes Δb ="HD 24190 minus HR 1163", plotted as a function of phase of the period of $1^{\mathrm{d}}.759$. The epoch of phase zero is HJD 2441650. Filled circles represent observations obtained between November 1972 and February 1973, whereas open circles, those obtained between August and November 1973. The scatter is due in part to HR 1163

The program star, HR 1163, is a double-lined spectroscopic binary. According to Blaauw & van Hoof (1963), who derived orbital elements of the system, the orbital period is $1^{\mathrm{d}}.940564 \pm 0^{\mathrm{d}}.000004$ (p.e.).

As we already mentioned, in the power spectrum of the residuals left after prewhitening the differential magnitudes "HD 23478 minus HR 1163" with the frequency 0.9525 c/d and its first harmonic, the highest peak occurred at 1.0267 c/d. At the same frequency the highest peak occurs in the power spectrum of "HD 24190 minus HR 1163" prewhitened with the frequency 0.5685 c/d. In both cases, the peak is flanked by ±1 cycle per year (c/y) side-lobes of significant height. The frequency of the +1 c/y one, equal to 1.0306 c/d, corresponds precisely to half the above-mentioned orbital period of HR 1163, that is $0^{\mathrm{d}}.9703$. We conclude that the peak at 1.0267 c/d is due to an ellipsoidal variation of HR 1163 with this period.

The amplitude of the variation is equal to 2.0 ± 0.5 mmag. Using this value, Eq. (2), and the orbital elements of the system, one gets i equal to about 25°.

4.3. *HR 1333 and 1 Cam*

Both these stars are program stars, although 1 Cam was C2 for P = HR 1333. On two nights, JD 2441715 and JD 2441992, HR 1333 was brighter than its mean magnitude by about 20 mmag. Standard deviations, computed using the data obtained on the remaining nights, turned out to be (in the same order as in Tab. 3): 1.4, 3.0, and 2.8 mmag. These numbers indicate that 1 Cam is a small amplitude variable, while HR 1330 is constant in light. The fortunate circumstance that except for the above-mentioned two nights, the differential magnitudes "HR 1333 minus HR 1330" have standard deviation even below the 1.8 mmag limit makes it possible to investigate the small light-variation of 1 Cam.

For this purpose we computed a power spectrum of the differential magnitudes "1 Cam minus the mean of HR 1333 and HR 1330", using all observations except those obtained on JD 2441715 and JD 2441992. In the frequency interval from 2 to 6 c/d, a number of peaks of almost the same height appeared, the highest at 4.5185 c/d. The corresponding period of $0^{\rm d}\!\!.22132$ falls in the range of periods typical for β Cep stars, but a sine-wave fit using this period has a standard deviation equal to 2.0 mmag, somewhat larger than the above-mentioned value of 1.4 mmag, and the amplitude equal to only 3.4± 0.5 mmag. Furthermore, the star was seldom observed more often than once per night, so that the period may be spurious. We conclude that further observations are necessary before 1 Cam can be classified as a β Cep-type star.

4.4. *HR 1924*

The total Hange of the differential magnitudes "HR 1924 minus the mean of HR 1902 and HR 1938" amounts to almost 50 mmag, but on three of the four nights when more than one observation was taken the range did not exceed 2 mmag, and on one, 4 mmag. Therefore, the period–if it exists–is certainly longer than half a day. Unfortunately, the data are insufficient to derive one. In addition, the radial velocity observations of the star, reported by Petrie (1958) and Blaauw & van Albada (1963), are somewhat inconsistent. While Petrie (1958) maintains that HR 1924 is a spectroscopic binary with a range of 63 km/s, Blaauw & van Albada (1963) list 15 measurements showing a range of only 20 km/s. More observations are thus needed to decide the type of variability. However, HR 1924 is definitely not a β Cep-type star.

4.5. *HR 2479*

The period, if one exists, is probably longer than $0^{\rm d}\!\!.3$. However, the data are insufficient to exclude the possibility that the star is a multiperiodic β Cep variable.

4.6. *HR 2633*

The period, if one exists, is longer than half a day.

4.7. *HR 3952*

The period which best fits the differential magnitudes "HR 3952 minus the mean of HD 86516 and HR 4012" is equal to $2^{\rm d}\!\!.86$. The standard deviation and the amplitude of the corresponding least-squares solution amount to 3.3 mmag and 5.3 ± 1.0 mmag, respectively. However, the data are so meager that this result may be spurious.

4.8. *λ Lib*

This star is a single-lined spectroscopic binary, although double lines have been suspected on one plate by Campbell & Moore (1928). According to Levato et al. (1987), the orbital period is equal to $14^{\rm d}\!\!.4829$ and the radial-velocity amplitude amounts to 28.5 km/s. Batten et al. (1989) rate the orbit as poor.

Because of the low declinations of about −20°, λ Lib and the comparison stars, C1 = HR 5934 and C2 = HD 142805, were always observed through air masses greater than 1.8. Hence, observational errors were in this case greater than usual. Even so, the standard deviations in Table 3 indicate that λ Lib is variable in light. Somewhat surprinsingly, a since curve with the period equal to half the orbital period fits the differential magnitudes "λ Lib minus HD 142805" quite well, suggesting an ellipsoidal variation with an amplitude equal to that of the sine curve, that is 5.8 ± 1.3 mmag. The problem is that this value is much too large: according to Eq. (2), the amplitude of a B2.5 V ellipsoidal variable with a period that long does not exceed 0.5 mmag. A solution of this problem is indicated by the fact that a shorter period, close to half the 1 c/sd alias of the orbital period, that is $0^{\rm d}\!\!.536$, fits our data even better than the one used before. The differential magnitudes "λ Lib minus HD 142805", phased with the period of $0^{\rm d}\!\!.536$, are shown in Fig. 6. The sine curve, seen in this figure, has an amplitude equal to 6.8 ± 1.2 mmag. It fits the data with a standard deviation equal to 3.3 mmag. We suggest that the period derived by Levato et al. (1987) is in error by about 1 c/sd, so that the true value of the orbital period of λ Lib is close to $1^{\rm d}\!\!.07$.

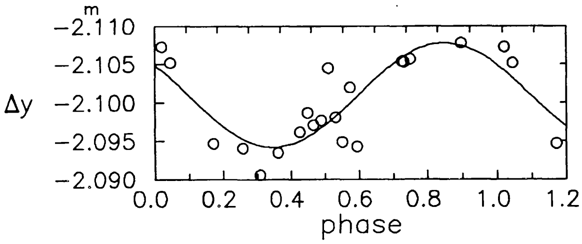

Fig. 6. Differential magnitudes Δy ="λ Lib minus HD 142096" (circles), plotted as a function of phase of the period of $0^{\rm d}\!\!.536$, and a sine curve of this period (solid line), fitted to the data by the method of least squares. The epoch of phase zero is HJD 2441830. The data were obtained in the interval from 30 May to 26 June 1973

Adopting this value of the orbital period and estimating the mass and radius of the star from its spectral type (Underhill 1982, Tables 2-11 and 2-12), we find from Kepler's third law and Eq. (2) that the above-mentioned amplitudes of the radial-velocity and light variations are both reproduced if the orbital inclination is equal to about 30° and the system's secondary has a mass equal to about 1.5 solar masses.

The first comparison star, C1 = HR 5934, was classified by Hill (1967) as a tentative β Cep variable. Hill (1967) obtained a period of $0\overset{d}{.}2872$ and amplitudes equal to 7 mmag and 6.5 mmag in B and U, respectively. Levato et al. (1987) found the radial velocity of HR 5934 to vary with a period equal to $10\overset{d}{.}0535$ and derived an orbit. Batten et al. (1989) rate the orbit as very poor.

The period which best fits our data is equal to $0\overset{d}{.}2854$, rather close to that obtained by Hill (1967). However, this period is also close to the 3 c/sd alias of a period equal to exactly 2 days, and therefore is almost certainly spurious.

4.9. *HR 6684 = V2052 Oph*

As mentioned in the Introduction, this star was discovered to be a β Cep variable early in the present program, from observations carried out in the spring of 1972. Additional observations were obtained in the interval from 15 June to 27 August 1973. The results, in the form of differential magnitudes VAR = "HR 6684 minus the mean of HR 6689 and HD 163792" and CST = "HD 163792 minus HR 6689", are plotted in Fig. 7.

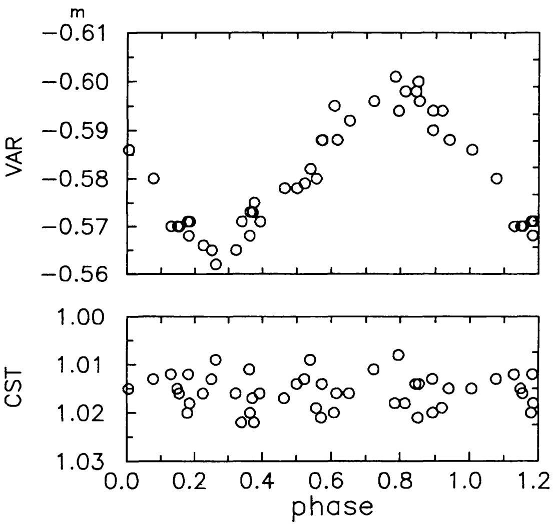

Fig. 7. Differential magnitudes VAR = "HR 6684 minus the mean of HR 6689 and HD 163792" (top) and CST = "HD 163792 minus HR 6689" (bottom) phased with the period of $0\overset{d}{.}13989$. The epoch of phase zero is HJD 2441850

Subsequent investigations of the star include those by Bolton et al. (1975) and by Kubiak & Seggewiss (1984).

4.10. *HD 164257*

This star was C1 for HR 6719. The LS power spectrum of the differential magnitudes Δy = "HD 164257 minus HR 6690" is shown in Fig. 8. The highest peak occurs at 1.1024 c/d. The data, phased with the corresponding period of $0\overset{d}{.}9071$, are plotted in Fig. 9. The best fitting sine curve of this period (not shown), has an amplitude equal to 6.4 ± 0.8 mmag and reduces the standard deviation to 2.9 mmag. The latter number and the "P minus C2" standard deviation in Table 3 imply that C2 = HR 6690 is probably constant, while P = HR 6719 may be slightly variable.

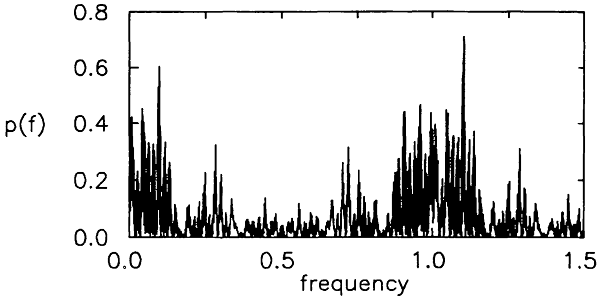

Fig. 8. The LS power spectrum of the differential magnitudes "HD 164257 minus HR 6690"

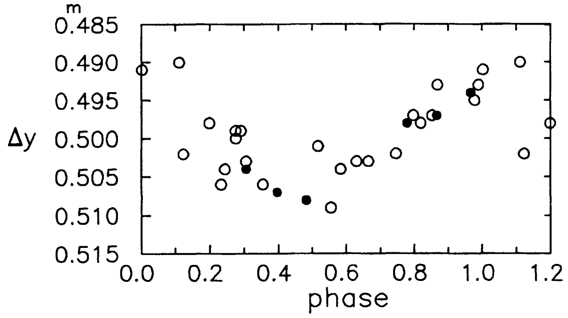

Fig. 9. Differential magnitudes Δy = "HD 164257 minus HR 6690", plotted as a function of phase of the period of $0\overset{d}{.}9071$. The epoch of phase zero is HJD 2441520. Filled circles represent observations obtained in July 1972, whereas open circles, those obtained between March and July 1973

HD 164257 may be an ellipsoidal variable. Assuming this to be the case and making the same calculations as those in Sub-section 4.2, but with the values of mass and radius typical for an AO V star, we can reproduce the observed light amplitude provided that $50° < i < 90°$ and $1 > q > 0.4$. The predicted radial-velocity range is then $230\ \mathrm{km/s} > 2K > 140\ \mathrm{km/s}$. Unfortunately, no radial-velocity observations are available to verify this prediction.

4.11. *96 Her*

This star was C1 for 102 Her. According to Koubsky et al. (1985), 95 Her is a spectroscopic multiple system, consisting of at least three components. For the binary formed by two brightest components, these authors derive a period equal to $12\overset{\mathrm{d}}{.}4573$. In addition, they find that the B magnitude of 96 Her varies with the orbital period; the light curve has an amplitude of about 10 mmag, and the light maximum coincides with the time of periastron passage. Koubsky et al. (1985) speculate that "a kind of pulsation driven by the tides is the source of the photometric variability."

The period which best accounts for our observations of 96 Her is equal to $0\overset{\mathrm{d}}{.}637$, but $1\overset{\mathrm{d}}{.}76$ is also possible. However, in either case the standard deviation of a sine-curve fit is geater than 4 mmag, so that both these periods may be spurious. The period of $12\overset{\mathrm{d}}{.}4573$ does not fit our data at all.

4.12. *HD 181492*

This star was C1 for HR 7335. The longest period which fits the differential magnitudes "HD 181492 minus the mean of HR 7335 and HD 180844" is equal to $2\overset{\mathrm{d}}{.}451$. The standard deviation and the amplitude of the corresponding sine-curve solution amount to 3.8 mmag and 7.2 ± 1.2 mmag, respectively. However, several aliases of this period also fit the data.

4.13. ω^1 *Cyg and HR 7870*

The period of ω^1 Cyg may be equal to $1\overset{\mathrm{d}}{.}792$ or $0\overset{\mathrm{d}}{.}6406$, but in both cases the standard deviation of a sine-curve fit amounts to as much as 5.5 mmag. Analysis of the data after prewhitening with either value failed to reveal further periodicities. In Fig. 10, the differential magnitudes Δb = "ω^1 Cyg minus HD 195965" are plotted as a function of phase of the shorter period.

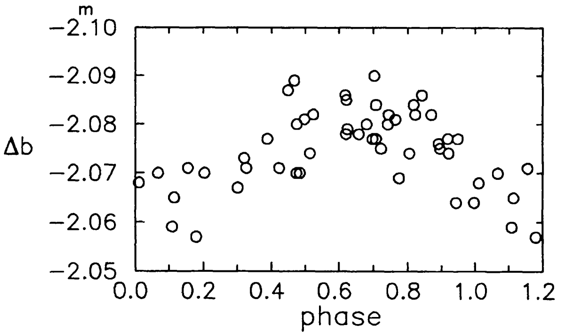

Fig. 10. Differential magnitudes Δb = "ω^1 Cyg minus HD 195965", phased with the period of $0\overset{\mathrm{d}}{.}6406$. The epoch of phase zero is HJD 2441850. The data were obtained in the interval from 21 June to 29 September 1973

There are two possibilities: (1) the light variation of ω^1 Cyg is erratic, both periods being merely artefacts of the analysis, or (2) in addition to a periodic variation, an erratic component is present. In view of the large number of observations, the first possibility seems unlikely. On the other hand, the periodic variation may be due to rotational modulation. Assuming this to be the case, and using the radius estimated from the stars's spectral type of B2.5 IV, we find that the equatorial velocity of rotation is equal to 147 km/s for the longer period, and to 411 km/s for the shorter one. According to the Bright Star Catalogue (Hoffleit 1982), the v sin i of ω^1 Cyg is equal to 184 km/s. This value rules out the longer period, but can be reconciled with the shorter one if $i = 27°$. If the shorter period were equal to half the rotation period, we would have v = 205 km/s and $i = 64°$. We conclude that ω^1Cyg may be a λ Eri variable with a rotation period close to $0\overset{\mathrm{d}}{.}64$ or twice this value. The erratic component in the light variation of the star resembles irregular fluctuations or flickering, found by Balona (1990b) to accompany rotational modulation in λ Eri variables.

The standard deviations in Table 3 indicate that at least one of the comparison stars for ω^1 Cyg, HR 7870 or HD 195965, is a small-amplitude variable. The "HR 7870 minus HD 195965" power spectrum, shown in Fig. 11, is dominated by a peak at 0.994 c/d and its aliases. The differential magnitudes, phased with the corresponding period of $1\overset{\mathrm{d}}{.}006$, are plotted in Fig. 12 as open circles. A sine curve of this period (solid line) fits the data with a standard deviation of 2.0 mmag; it has an amplitude equal to 3.3 ± 0.4 mmag.

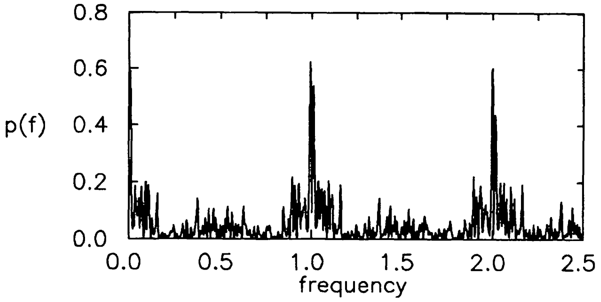

Fig. 11. The LS power spectrum of the differential magnitudes "HR 7870 minus HD 195965"

According to the Bright Star Catalogue (Hoffleit 1982), HR 7870 is a B9p Si star with v sin i = 55 km/s. Assuming that the photometric period of $1\overset{\mathrm{d}}{.}006$ is identical with the period of rotation of the star, and taking 3.2 $R_\odot$ as the star's radius, we obtain v = 160 km/s and $i = 20°$. We therefore conclude that HR 7870 is responsible for the light variation seen in Fig. 12 and that it should be counted among such rapidly rotating Si stars as 56 Ari and HD 124224 (Wolff 1983). On the other hand, the second comparison star, HD 195965, is constant in light.

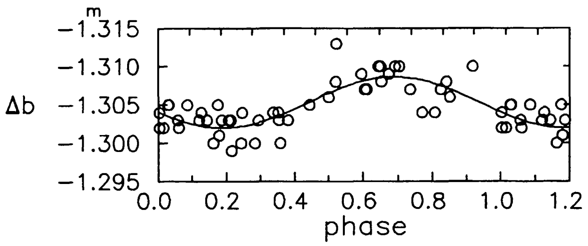

Fig. 12. Differential magnitudes Δb = "HR 7870 minus HD 195965" (circles), phased with the period of $1\overset{\mathrm{d}}{.}006$, and a sine curve of this period (solid line), fitted to the data by the method of least squares. The epoch of phase zero is HJD 2441850. The data were obtained at the same epochs as those shown in Fig. 10

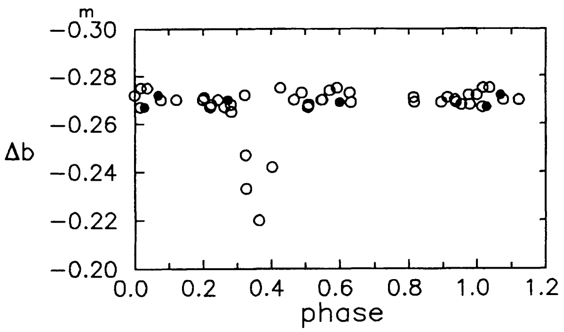

Fig. 13. Differential magnitudes Δb ="HR 7940 minus HD 198679", plotted as a function of phase of the period of $24\overset{\mathrm{d}}{.}45$. The epoch of phase zero is HJD 2441580. Filled circles represent observations obtained in September and November 1972, whereas open circles, those obtained in the interval from 28 May to 15 October 1973

4.14. *HR 7940*

Our data show that the star is an eclipsing variable. This can be seen from Fig. 13, where the differential magnitudes "HR 7940 minus HD 198679" are plotted as a function of phase of the period of $24\overset{\mathrm{d}}{.}45$. The period was derived by trial and error and is uncertain because of rather inadequate number of observations during eclipse.

4.15. *HR 8029*

In its photometric behaviour the star is similar to ω^1 Cyg. The periods that best fit the data are $1\overset{\mathrm{d}}{.}238$ and $5\overset{\mathrm{d}}{.}125$. They are 1 c/sd aliases of each other. Figure 14 shows the differential magnitudes "HR 8029 minus HD 198793" phased with the shorter period.

4.16. *HR 8105*

Several short periods fit the data. The best seems to be $0\overset{\mathrm{d}}{.}10809$. Differential magnitudes Δy ="HR 8105 minus HD 202126", phased with this period, are shown in Fig. 15. The star may be similar to such short-period β Cep variables as HR 3088 = V372 Car (Jerzykiewicz & Sterken 1977) or HDE 326333 = NGC 6231−150 = V920 Sco (Shorbbrook 1979; Balona 1983).

A $0\overset{\mathrm{d}}{.}10809$ sine-curve can be also fitted to the radial-velocity observations of HR 8105, published by Plaskett & Pearce (1931). The resulting velocity amplitude amounts to $K = 6.5 \pm 1.7$ km/s. However, the observations consist of only six data points spread over an interval of almost two years, so that the fit is probably spurious.

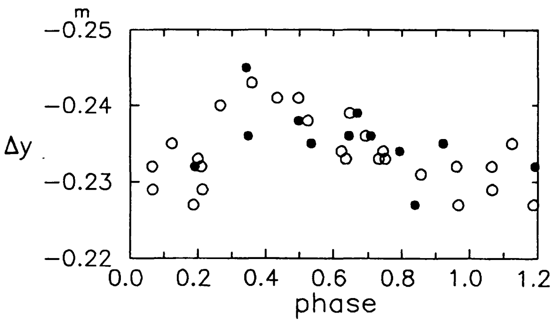

Fig. 14. Differential magnitudes Δb ="HR 8029 minus HD 198793", plotted as a function, of phase of the period of $1\overset{\mathrm{d}}{.}238$. The epoch of phase zero is HJD 2441600. Filled circles represent observations obtained in October and November 1972, whereas open circles, those obtained in the interval from 23 June to 29 September 1973

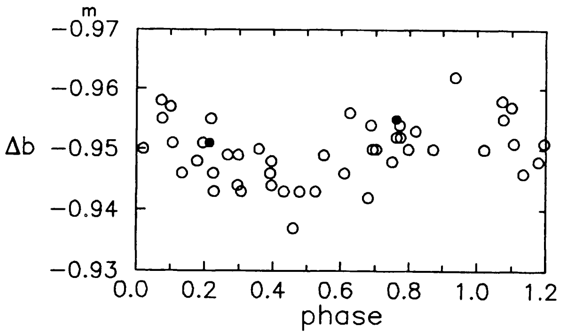

Fig. 15. Differential magnitudes Δy ="HR 8105 minus HD 202126", plotted as a function of phase of the period of $0\overset{\mathrm{d}}{.}10809$. The epoch of phase zero is HJD 2441600. Filled circles represent observations obtained in the interval from 13 October to 2 December 1972, whereas open circles, those obtained from 23 June to 29 September 1973

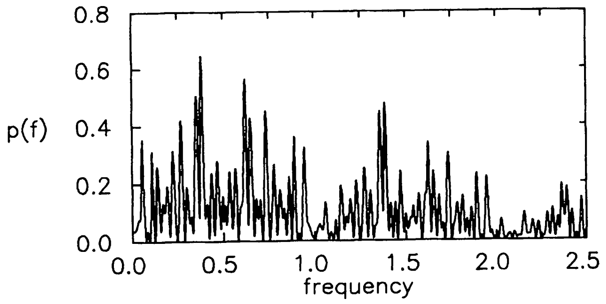

Fig. 16. The LS power spectrum of the 1973 differential magnitudes "HR 8706 minus the mean of HR 8733 and HR 8723"

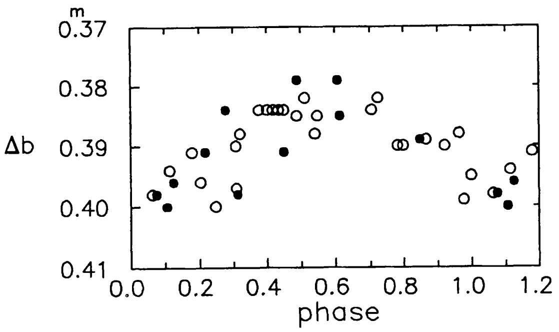

Fig. 17. Differential magnitudes Δb ="HR 8706 minus the mean of HR 8733 and HR 8723", phased with the period of $2^{\mathrm{d}}.6217$. The epoch of phase zero is HJD 2441580. Filled circles represent observations obtained in the interval from 26 September to 30 December 1972, whereas open circles, those obtained in September and October 1973

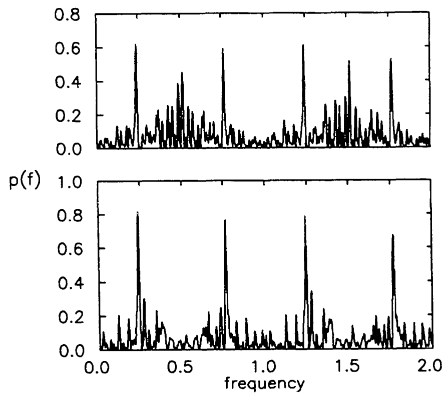

Fig. 18. The LS power spectra of the 1973 differential magnitudes "HR 8777 minus HR 8808" (top) and "HR 8777 minus HR 8803" (bottom)

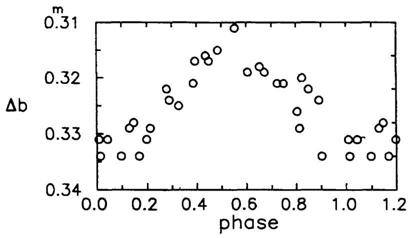

Fig. 19. Differential magnitudes Δb ="HR 8777 minus HR 8803", phased with the period of $4^{\mathrm{d}}.20$. The epoch of phase zero is HJD 2441880. The observations were obtained in the interval from 23 July to 15 October 1973

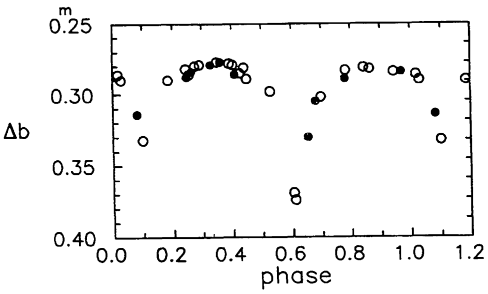

Fig. 20. Differential magnitudes Δb ="HR 8854 minus HR 8803", plotted as a function of phase of the period of $2^{\mathrm{d}}.3913$. The epoch of phase zero is HJD 2441500. Filled circles represent observations obtained in the interval from 26 September to 26 December 1972, whereas open circles, those obtained in September and October 1973

4.17. *HR 8706*

In 1972 the star was observed as C1 for HR 8733 and found to be variable in light. In 1973 it was re-observed, with HR 8723 and HR 8733 used as comparison stars. Fortunately, these two stars turned out to be constant.

In the LS power spectrum of the 1973 differential magnitudes "HR 8706 minus the mean of HR 8733 and HR 8723", shown in Fig. 16, the highest peak corresponds to a period of $2^{\mathrm{d}}.62$. This period fits also the 1972 differential magnitudes "HR 8706 minus HR 8733". An improved value of the period, derived from both sets of data, is equal to $2^{\mathrm{d}}.6217 \pm 0^{\mathrm{d}}.0012$. In Fig. 17, where all observations of HR 8706 are plotted as a function of phase of this period, the 1972 differential magnitudes are shown shifted by half the mean difference between the magnitudes of HR 8733 and HR 8723.

The scatter in Fig. 17 around the best fitting sine curve is characterized by a standard deviation equal to 3.8 mmag, a value much larger than the corresponding "C1 − C2" standard deviation in Table 3. This indicates that the variation of HR 8706 is multiperiodic, or that it contains an erratic component, or both. Unfortunately, the data are insufficient to decide which of these possibilities is the case.

As far as the cause of variability is concerned, none of the three possibilities discussed in Sub-sect. 4.2 in connection with HD 23478 can be rejected because all that is known about the radial velocity of the star is a single mean value based on four plates taken at unspecified epochs (Shajn & Albitzky 1932). We note, however, that the period, MK type of B7 III-IV and $v \sin i = 15$ km/s (Hoffleit 1982) make HR 8706 similar to the mid-B variables of Waelkens & Rufener (1985).

4.18. *HR 8758*

In 1972 the star was observed as C2 for HR 8733 and found to be variable in light. In 1973 it was re-observed, with the same comparison stars as those used for HR 8706, that is, HR 8723 and HR 8733.

The light variation of HR 8758 is dominated by noise. No period could be found that would reduce the standard deviation by more than 20 percent.

4.19. *HR 8777*

This star was C1 for HR 8803. From observations obtained in 1973, when C2 was HR 8808, it is clear that HR 8777 is variable (see Tabs. 2 and 3). However, the standard deviations in Table 3 indicate that at least one of the other two stars, HR 8803 or HR 8808, is also variable, but with a smaller amplitude.

The power spectra of "HR 8777 minus HR 8808" and "HR 8777 minus HR 8803" are displayed in Fig. 18 (top and bottom panels, respectively). Both are dominated by a peak at 0.238 c/d and its aliases, the highest at 1.241 c/d, but the top spectrum shows also a noisy pattern with peaks around 0.5 and 1.5 c/d. We conclude that (1) the variation of HR 8777 is periodic, and (2) of the other two stars, HR 8808 is the variable.

The periods corresponding to the above-mentioned highest peaks in Fig. 18 are equal to $4\overset{d}{.}20$ and $0\overset{d}{.}806$. In Fig. 19, the differential magnitudes $\Delta b =$"HR 8777 minus HR 8803" are plotted as a function of phase of the longer period. A sine curve of this period fits the data with a standard deviation equal to 2.9 mmag.

The same arguments as those used in Sub-section 4.2 lead to the conclusion that for the photometric period as long as $4\overset{d}{.}20$ the maximum b amplitude of an ellipsoidal variation would be 1.5 mmag, much smaller than the observed one. For the shorter period, the computed and observed amplitudes can be matched, but then the range of the radial-velocity variation would have to be equal to at least 85 km/s, while the observed range amounts to 52 km/s (Plaskett & Pearce 1931). We conclude that HR 8777 is not an ellipsoidal variable.

4.20. *HR 8808*

Although 51 differential magnitudes "HR 8808 minus HR 8803", obtained from observations on 28 nights between 23 July and 15 October 1973, were available for analysis, so satisfactory period could be found.

4.21. *HR 8854 = V649 Cas*

An examination of the differential magnitudes "HR 8854 minus HR 8803" shows that the star is an eclipsing variable. The period, found by trial and error, is equal to $2\overset{d}{.}3913$. The light curve is presented in Fig. 20.

The above result was already reported by Jerzykiewicz & Sterken (1982). Eclipses were also detected by Gulliver et al. (1982). The star was shown to be a double-lined spectroscopic binary by Gulliver et al. (1985). The latter authors found the period to be $2\overset{d}{.}391253$ and derived an orbit. A light-curve analysis of HR 8854 was carried out by Martin et al. (1990b).

5. Summary and discussion

Main results of the preceding section are summarized in Table 4. The three known variable stars, V467 Per, V2052 Oph, and V649 Cas, are not included, because our results were superseded by later work, referenced in Sub-section 4.1, 4.9, and 4.21, respectively. By "Amplitude" (third column) we mean either the parameter A in the relation $A \sin (2\pi/P + \phi)$, where P is the period from column two, or the observed half-range. A's were computed by the method of least squares; their mean errors and the standard deviations of the least-squares fits (s.d.) are also given, the latter in column four. In the last column, in addition to the standard notation from the fourth edition of the General Catalogue of Variable Stars (Kholopov et al. 1985) for the well-known types of variability, the self-explanatory labels "λ Eri" and "mid-B" are used.

Except for HD 164257, HR 7870, and HR 8706, the stars in Table 4 have spectral types B3 or earlier. As far as the type of variability is concerned, we found that of the three later spectral type stars, HD 164257 (AO) may be an ellipsoidal variable, HR 7870 (B9p Si) is an α^2 CVn variable, and HR 8706 (B7 III-IV) is probably a "mid-B" variable. Of the earlier spectral type stars, HR 7940 (B2 III) is an eclipsing variable, HR 1163 and λ Lib (both B2.5 V) are ellipsoidal variables, HD 23478 (B3 IV) and ω^1 Cyg (B2.5 IV) are λ Eri stars, 1 Cam (B0 IIIn) and HR 8105 (B0.5 IVn) may be β Cep variables, and the twelve remaining variables could not be classified because of insufficient data. Of the latter, in all but HR 2479 (B0 III) we excluded periods shorter than $0\overset{d}{.}5$; thus they cannot be β Cep stars. In the case of HR 2479, the data are insufficient to exclude the possibility that it is a multiperiodic β Cep variable.

Table 4. Twenty-two new variable stars

Star	Period [day]	Amplitude [mmag]	s.d. [mmag]	Type
HD 23478	1.0499	6.4 ± 0.4	2.0	λ Eri
	1.0499/2	2.0 ± 0.4		
HD 24190	1.759	3.7 ± 0.5	2.1	?
HR 1163	0.9703	2.0 ± 0.5	2.2	ELL
HR 1333	?	10	- -	?
1 Cam	0.22132?	3.4 ± 0.5	2.0	BCEP?
HR 1924	>0.5	24	- -	?
HR 2479	>0.3	14	- -	?
HR 2633	>0.5	15	- -	?
HR 3952	2.86?	5.3 ± 1.0	3.3	?
λ Lib	0.536	6.8 ± 1.2	3.3	ELL
HD 164257	0.9071	6.4 ± 0.8	2.9	ELL?
96 Her	0.637?	6.9 ± 1.1	4.4	?
HD 181492	2.451	7.2 ± 1.2	3.8	?
ω^1 Cyg	0.6406	8.0 ± 1.2	5.5	λ Eri
HR 7870	1.006	3.3 ± 0.4	2.0	ACV
HR 7940	24.45?	see Fig. 13	- -	EA
HR 8029	1.238	5.5 ± 1.0	3.9	?
HR 8105	0.10809?	5.0 ± 0.9	3.2	BCEP?
HR 8706	2.6217	6.9 ± 0.9	3.8	mid-B?
HR 8758	?	18	- -	?
HR 8777	4.20	8.6 ± 0.8	2.9	not ELL
HR 8808	?	10	- -	?

We classified HD 23478 and ω^1 Cyg as λ Eri variables, although they are not Be stars, because we regard rotational modulation to be the most likely cause of their variability. Other stars which may belong to this category of "non-Be λ Eri variables" are HD 25799 (B3 V), λ Col (B5 V), and σ Lup (B2 III). HD 25799 is listed among the λ Eri variables by Balona (1990a). The period of λ Col, equal to $0^{\mathrm{d}}.640$ (Jerzykiewicz and Sterken 1977), is inconsistent with an assumption of an ellipsoidal variation but not with that of rotational modulation. Finally, in the case of σ Lup rotational modulation has been found to be a reasonable working hypothesis by Jerzykiewicz and Sterken (1992).

The "non-Be λ Eri variables" may simply represent λ Eri stars in a quiescent state between Be outbursts. However, a more interesting possibility is that rotational modulation occurs not only in Be, but also in otherwise normal B stars.

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