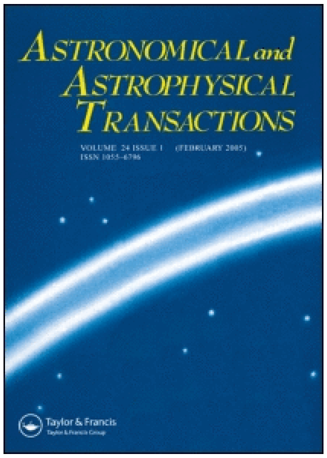

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PHOTOMETRIC CLASSIFICATION OF POORLY KNOWN VARIABLES S 8348=NSV 12742, S 8351=HT VUL AND S 8352=NSV 12763

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The stars were studied on negatives of the Sternberg State Astronomical Institute and the Abastumani Astrophysical Observatory. The stars are classified as EB (NSV 12742, $P = 0\overset{d}{.}4662417$), SX Phe (HT VUL, $P = 0\overset{d}{.}12677192$) and EA (NSV 12763, $P = 1\overset{d}{.}735215$).

KEY WORDS Stars: eclipsing, pulsating

1 INTRODUCTION

The variability of all these stars was discovered by Hoffmeister (1964) who suspected that they belong to E, RR and E types of variability. However, no photometric elements were derived, thus this classification was only a preliminary one. The stars are located in the field QQ Vul which was intensely observed in 1986–1988 at the Schmidt camera of the Abastumani Astrophysical Observatory (AAO) by

Table 1.

	S 8348	*S 8351*	*S 8352*
a	14.48 ± 0.06	15.29 ± 0.12	15.13 ± 0.08
b	15.68 ± 0.09	15.47 ± 0.10	15.92 ± 0.11
c	16.81 ± 0.12	15.66 ± 0.08	16.25 ± 0.10
d	16.98 ± 0.13	15.75 ± 0.09	16.48 ± 0.13
e	18.01 ± 0.17		

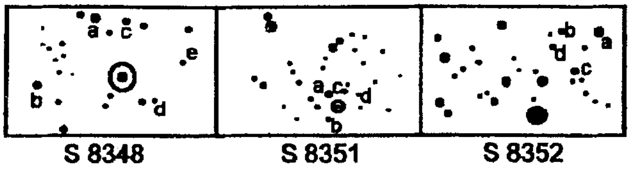

Figure 1 Finding charts for the investigated stars.

G. N. Kimeridze, I. L. Andronov, S. V. Kolesnikov and N. V. Poplavskaya (Andronov *et al.*, 1989). As these nearly 500 negatives were obtained during 20 nights, this material was an exellent to obtain individual light curves and classify the stars. To obtain data from longer time intervals, we have used the negatives of the Sternberg State Astronomical Institute (SAI) which allowed us to check the classification and to obtain more precise photometric periods. The photometric systems are close to pg: the film A-500 for the AAO negatives, and the plates ZU-2, ZU-21 (SAI collection).

The brightness of the comparison stars was determined by using the SAI iris-photometer and are listed in Table 1

The finding charts are shown in Figure 1.

2 S 8348=NSV 12742: A HIGH-AMPLITUDE EB-TYPE VARIABLE

Hoffmeister (1964) suspected that this is an eclipsing binary varying with a small amplitude from 14.5 to 15. It was measured on 422 AAO negatives.

The periodogram analysis was carried out by using the program FOUR-1 (Andronov, 1994) realizing one-harmonic sine fit to the phase curve. As the test function, we have used the ratio $S(f) = \sigma_C^2 = \sigma_O = 1 - \sigma_{O-C}^2/\sigma_O^2$. The periodogram is shown in Figure 2.

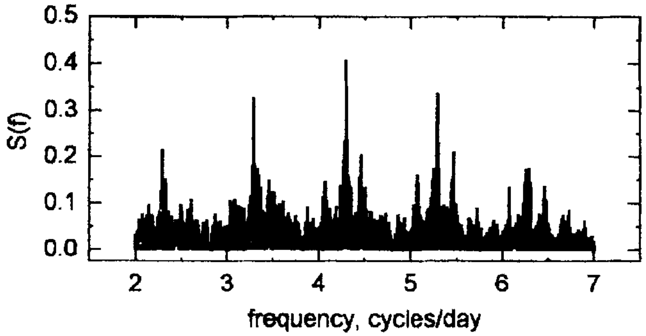

Figure 2 Periodogram $S(f)$ for the brightness variations of S 8348. The most prominent peak corresponds to the orbital one multiplied by a factor of 2.

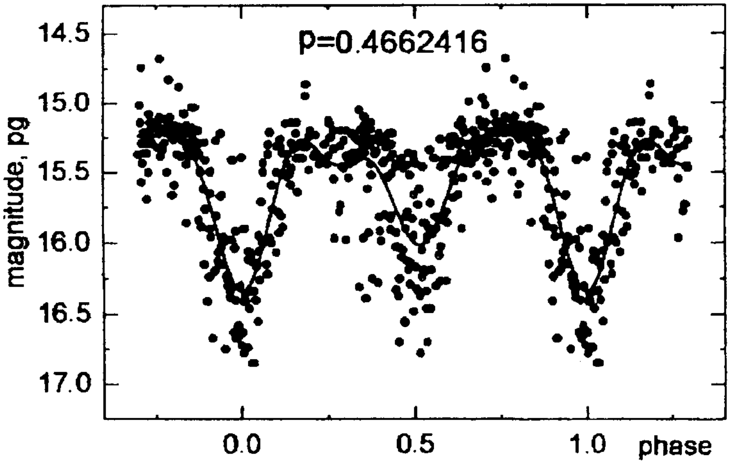

Figure 3 Phase light curve of S 8348. The solid line represents a four-harmonic fit.

The most prominent peak corresponds to a period twice smaller than the above mentioned value. Examination of the phase curve showed that the star belongs to the EB type, thus there are two waves during the period. To fit the phase curve we have used the multiharmonic approximation with differential corrections to the frequency (the program FOUR-M by Andronov, 1994)

$$m(\phi) = a_0 - \sum_{k=1}^{s} r_k \cos(2\pi k(\phi - \phi_k)). \tag{1}$$

The number of statistically significant harmonics is $s = 4$. The parameters of best fit are the following:

The elements:

$$\begin{array}{rll} Min.\ HJD = & 2447078.4027 + & 0.4662417 \cdot E \\ & \pm 18 & \pm 15 \end{array} \tag{2}$$

The duration of the eclipse is $d = 0.26P$. The extrema are shown in Table 2. The phase curve is shown in Figure 3.

Table 2.

	m_{pg}	*phase*
Minimum I	16.34 ± 0.4	0.000 ± 0.004
Maximum I	15.27 ± 0.4	0.18
Minimum II	16.02 ± 0.4	0.51
Maximum II	15.21 ± 0.4	0.789 ± 0.026

The individual minima are *HJD* 2446620.410, 6621.426, 6638.284, 7355.302, 7356.320, 7359.366, 7360.378, 7419.350 with an accuracy estimate derived from a parabolic fit of $0\overset{\mathrm{d}}{.}0016$ for the first three minima and of $0\overset{\mathrm{d}}{.}0013$ for the rest.

The eclipse depth estimates of $1\overset{\mathrm{m}}{.}13$ and $0\overset{\mathrm{m}}{.}81$ are surprisingly large. Assuming a crude model of two spherical stars and an inclination angle $i = 90^\circ$, one obtains joint brightness 17^{m} smaller than the brightness at maximum. This difference increases if one or two of the minima are partial, caused by differences in radii and/or $i < 90^\circ$. One of the explanations of the "extra" flux at maximum is caused by the effect of ellipticity and/or reflection. A non-physical explanation is that there is a magnitude scale distortion caused by errors in the determination of the brightness of comparison stars on the photographic plates. The weakest observations are close to the plate limit ($\approx 18^{m}$), thus the errors for weak comparison stars are larger than for the brighter ones.

Our observations do not confirm Hoffmeister's (1964) remark about "very small amplitude". The difference in mean magnitude may be caused both by the difference in the instrumental systems (the film A-500 in Abastumani, plates ZU-2 in Sonneberg) and by errors of linking the stars to the standard. The star is an interesting target for CCD observations because of its large amplitude and high inclination.

3 S 8351=HT VUL: A 3-HOUR, 0.9-MAG PULSATING VARIABLE

Hoffmeister (1964) suspected that star belongs to the RR Lyr-type and changes its photographic brightness from $15\overset{\mathrm{m}}{.}5$ to $16\overset{\mathrm{m}}{.}5$. Although no period was found, it was included in GCVS III and IV (Kholopov *et al.*, 1987) owing to its high amplitude and received the designation HT Vul.

The star was measured on 199 AAO films and on 398 SAI plates. The object was found to be a short-period pulsating variable from the light curves obtained during individual mights. The periodogram analysis was carried out by using the program FOUR-1 (Andronov, 1994). The periodograms for the AAO and SAI data are shown separately in Figure 4. As the duration of the SAI observations is much longer, the periodogram shows one most prominent peak without apparent aliases. However, the strong daily and yearly aliases are present for the AAO data.

To fit the phase curve (Figure 5) we have used the multiharmonic approximation (the program FOUR-M by Andronov, 1994). For the AAO data the number of statistically significant harmonics is $s = 3$. The r.m.s. deviation of the data from the smoothing curve is rather high ($0\overset{\mathrm{m}}{.}21$) arguing for possible changes of the light curve. The mean brightness is $\langle m \rangle = 15\overset{\mathrm{m}}{.}69$, the r.m.s. deviation from the mean $\sigma_0 = 0\overset{\mathrm{m}}{.}33$. The best fit period value for the AAO observations is $P = 0\overset{\mathrm{d}}{.}1267711 \pm 3 \times 10^{-7}$ which does not differ significantly from the value with better accuracy which was obtained from SAI data.

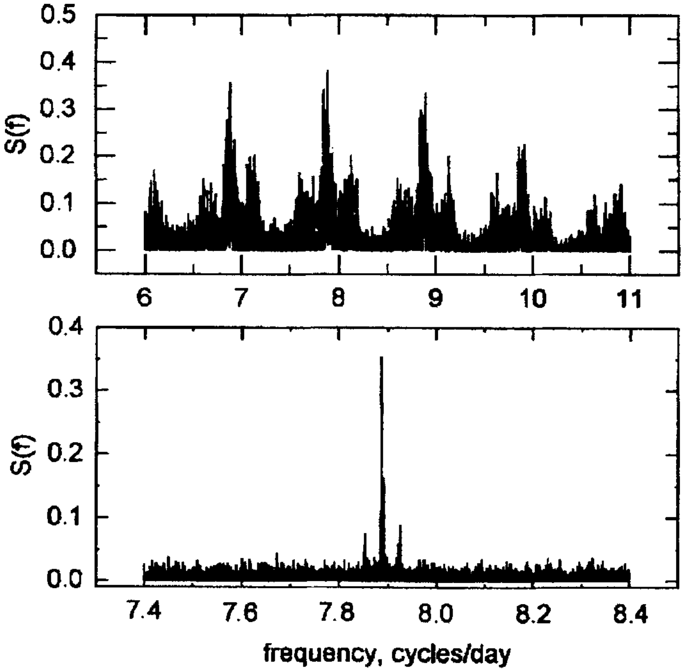

Figure 4 Periodogram $S(f)$ for the brightness variations of S 8351 for the AAO (top) and SAI (bottom) data.

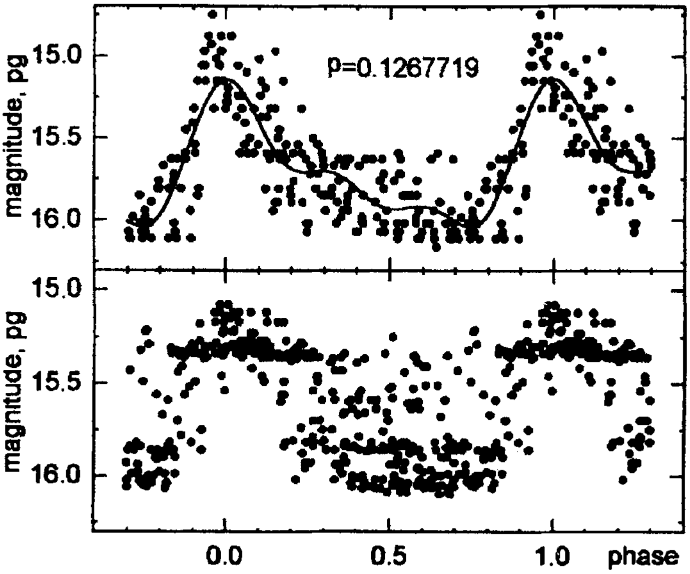

Figure 5 Phase light curve of S 8351 for the AAO (top) and SAI (bottom) data. The solid line represents a three-harmonic fit.

The elements (initial epoch from the AAO data, the period from the SAI data) are:

$$\begin{array}{rcl} Min.\,HJD = & 2447152.6079 & +\,0.12677192\cdot E \\ & \pm 8 & \pm 7 \end{array} \qquad (3)$$

Other parameters were obtained for the AAO fit. The asymmetry is $M - m = (0.255 \pm 0.013)P$, full amplitude $\Delta m = 0\overset{\mathrm{m}}{.}90 \pm 0\overset{\mathrm{m}}{.}04$, mean magnitude at maximum $15\overset{\mathrm{m}}{.}14 \pm 0\overset{\mathrm{m}}{.}04$, magnitude at minimum $16\overset{\mathrm{m}}{.}04 \pm 0\overset{\mathrm{m}}{.}04$.

To compare with theoretical models of observational data of pulsating variables (Kukarkin and Parenago, 1937; Kovacs *et al.*, 1986; Antonello, 1994), we list the characteristics of the individual harmonics of the fit in Table 3.

Table 3.

k	r_k	r_k/r_1	ϕ_k	$\phi_k - k \cdot \phi_1$
1	0.327 ± 0.022	1.00 ± 0.00	$+0.07 \pm 0.01$	0.000 ± 0.000
2	0.169 ± 0.022	0.52 ± 0.07	-0.01 ± 0.02	0.859 ± 0.030
3	0.103 ± 0.022	0.31 ± 0.07	-0.06 ± 0.03	0.748 ± 0.046

The individual maxima are *HJD* 2446620.324, 6621.482, 6626.395, 6639.410, 7355.345, 7356.265, 7360.468, 7419.410 with a similar accuracy estimate $0\overset{\mathrm{d}}{.}005$ derived from a parabolic fit.

The SAI plates were obtained with a typical exposure of 45 min, i.e. one quarter of the period. Thus the abrupt ascending branch is smoothed and the phase curve corresponds to the number of statistically significant harmonics $s = 1$ with formal value $M - m = 0.5$. The mean brightness is $\langle m \rangle = 15\overset{\mathrm{m}}{.}63$, the r.m.s. deviation from the mean is $\sigma_O = 0\overset{\mathrm{m}}{.}31$, and from the sine fit is $\sigma_{O-C} = 0\overset{\mathrm{m}}{.}25$, showing no signivical difference from the AAO data. The brightness at maximum is $15\overset{\mathrm{m}}{.}35 \pm 0\overset{\mathrm{m}}{.}02$, at minimum $15\overset{\mathrm{m}}{.}89 \pm 0\overset{\mathrm{m}}{.}02$. The corresponding amplitude $r_1 = 0\overset{\mathrm{m}}{.}270 \pm 0\overset{\mathrm{m}}{.}011$ does not differ from that for the AAO data within error estimates. However, the shift of the phase of the SAI data with respect to the AAO data is significant and is seen at the phase curve. It may be explained by the symmetrization of the phase curve caused by the high ratio of the exposure time to the period. The phase of the maximum of the main wave $\phi_1 = 0.065 \pm 0.010$ for the AAO data coincides with the phase of the main (and only) wave for the SAI data $\phi_1 = 0.074 \pm 0.012$ within error estimates.

The large scatter seen in the SAI data may be explained by the observational noise due to the proximity of the star to the plate border on some negatives. This may cause the apparent observational clustering of the data near some preferred magnitudes as the digitizing step grows. Another possibility is the physical variability of the phase light curve which is usual for both δ Sct and SX Phe-type stars. However, it is not possible to make accurate conclusions on the character of these secondary changes, since they are based on patrol observations rather than complete phase curves.

Despite the fact that the scatter of the phase curve for the SAI data is larger than for the AAO data, the amplitudes and phases of the main harmonic wave are in exellent agreement. Thus we have used the initial epoch for AAO data (1986–1988) which is not shifted by long exposure and the period from SAI data with longer base (1963–1990).

The star HT Vul=S8351 may not be classified as an RR Lyr-type variable as its short period $0\overset{d}{.}127$ corresponds either to δ Sct or SX Phe-type stars. The majority of the SX Phe-type variables have periods from $0\overset{d}{.}04$ to $0\overset{d}{.}08$ (Kholopov *et al.*, 1985a), but one of the stars of this type, XX Cyg, has a much larger period $0\overset{d}{.}135$ and amplitude of $0\overset{d}{.}85$ (Kholopov *et al.*, 1985b), which are very similar to corresponding values obtained for HT Vul. Also similar are the values of the asymmetry $M - m = 0.255$ in HT Vul and $M - m = 0.22$ in XX Cyg. Thus the object may be classified as a SX Phe-type star.

4 S 8352=NSV 12763 IS AN ALGOL-TYPE STAR

Hoffmeister (1964) suspected that this star is an eclipsing binary. It was measured on 282 AAO and on 435 SAI negatives. The individual light curves and the histogram of the patrol observations have shown that the object is an EA-type eclipsing variable.

The moments of 14 weakenings and corresponding magnitudes are given in Table 4.

Table 4.

HJD 24...	*mag*	*HJD* 24...	*mag*
37168.4280	16.67	43321.4493	16.54
37175.3696	16.64	44194.2723	16.61
40118.2786	16.61	44442.3556	16.68
40779.3742	16.86	44763.4894	16.73
40819.2741	16.72	45530.3825	16.52
42667.2974	16.88	45530.3957	16.51
43047.3347	16.68	47359.3274	16.67

They were analysed by the program PERMIN (Andronov, 1991). The periodograms (Figure 6) shows the most prominent minimum at the period $P = 1\overset{d}{.}735210 \pm 5 \times 10^{-6}$, $T_0 = 2442636.063 \pm 0.008$, the r.m.s. deviation of the phase from zero $\sigma[\phi] = 0.016$. No period variation may be detected from these data.

Fitting the individual minima by a parabola, the following times were determined: *HJD* 2445530.3833 ± 0.0040 and 47359.3344 ± 0.0035.

The periodogram analysis was carried out by using the program LK by I. L. Andronov computing test-functions proposed by Lafler and Kinman (1965) in the modification by Kholopov (1970) and by Deeming (1970). The best-fit value of the

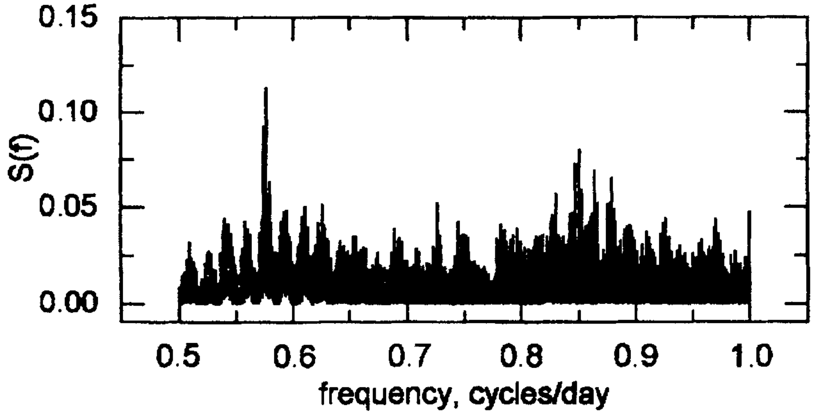

Figure 6 Periodogram S(f) for the brightness variations of S 8352 for the AAO data.

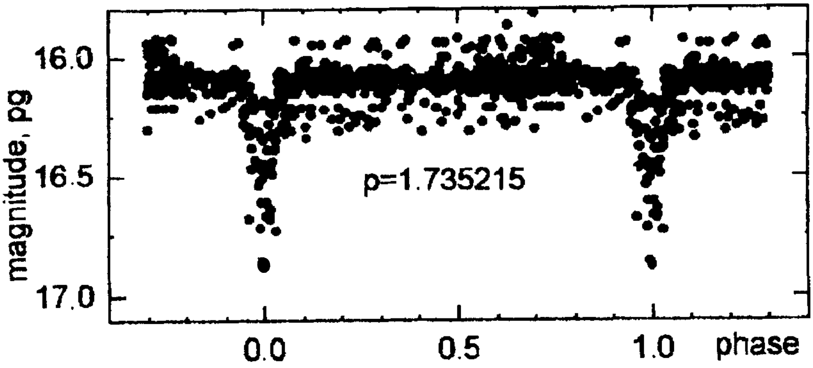

Figure 7 Phase light curve of S 8351 for the AAO and SAI data.

period corresponds to $P = 1\overset{\mathrm{d}}{.}735219$. A similar value $P = 1\overset{\mathrm{d}}{.}735223 \pm 15 \times 10^{-6}$ was obtained by using the program FOUR-1 (Andronov, 1994) realizing one-harmonic fit to the phase curve.

Unfortunately, the "non-parametric" methods such as those of Lafter and Kinman (1965) and Deeming (1970) do not allow us to determine the mean shape of the light curve and thus the phases of extrema. To fit the phase curve (Figure 7) we have used the multiharmonic approximation (the program FOUR-M by Andronov, 1994). For the AAO data the number of statistically significant harmonics is $s = 9$ which is what could be expected because of the narrow eclipse. The mean value is $\langle m \rangle = 16\overset{\mathrm{m}}{.}09$, the r.m.s. deviation from the mean $\sigma_O = 0\overset{\mathrm{m}}{.}11$, the weakest data point has $m = 16\overset{\mathrm{m}}{.}67$, but the magnitude of the minimum at the smoothing curve is $16\overset{\mathrm{m}}{.}37$. The period is $P = 1\overset{\mathrm{d}}{.}735208 \pm 32 \times 10^{-6}$, the initial epoch $Min.\ HJD = 2447154.577 \pm 0.004$, and the error estimate of a single observations is $\sigma_* = 0.072$.

Slightly different values were obtained for the SAI data: $s = 10$, $P = 1\overset{\mathrm{d}}{.}735211 \pm 3\times 10^{-6}$, $T_0 = 2440454.899 \pm 0.003$, $m_{\min} = 16\overset{\mathrm{m}}{.}88$ (individual point) and $m_{\min} = 16\overset{\mathrm{m}}{.}60$ (fit), $\langle m\rangle = 16\overset{\mathrm{m}}{.}15$, $\sigma_O = 0\overset{\mathrm{m}}{.}12$, $\sigma_* = 0.082$. The initial epochs differ by 3861 cycles, as they correspond to the times closest to the mean times of observations used for the fit. The difference between the values obtained for the mean magnitude and the magnitude at minimum may be explained by the small difference of the instrumental systems of the AAO and SAI observations.

Joining the AAO and SAI data, one may obtain the best-fit ephemeris for $n = 718$ observations:

$$\begin{array}{rcll} Min.\ HJD = & 2444102.3210 & + \ 1.7352152 & \cdot E \\ & \pm 30 & \qquad \pm 15 & \end{array} \tag{4}$$

$s = 9$, $\langle m\rangle = 16\overset{\mathrm{m}}{.}13$, $\sigma_O = 0\overset{\mathrm{m}}{.}13$, $\sigma_* = 0\overset{\mathrm{m}}{.}098$, $m_{\min} = 16\overset{\mathrm{m}}{.}45$. The duration of the eclipse is $d = 0.12P$, and the mean magnitudes $16\overset{\mathrm{m}}{.}06$.

The values of the period obtained by using different methods and for different data sets coincide within their error estimates.

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