# PERIODOGRAM ANALYSIS OF THE BRIGHTNESS VARIATIONS OF 8 RED SUSPECTED VARIABLES

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ABSTRACT. Eight red variables from the lists by Collins (1990, 1991) were measured on the plates of the Odessa plate collection. The results of the periodogram analysis are presented. TAV 0451+69 shows two oscillations with periods $242^d$ and $152^d$. TASV 0714+39 shows 3–harmonic wave with $P = 403.2^d$.

**Key words:** Stars: semiregular, Mira–type

### Observations and Preliminary Analysis

The new variable stars were measured on archive plates of the Astronomical Observatory of the Odessa State University by V.I.Marsakova (finding charts published by Collins (1990)) and S.V.Rottar (charts from Collins (1991)). The visual brightness of the comparison stars was used when measuring the photovisual plates ORWO ZP–3 exposed with a yellow filter. In some cases the values were corrected by using the arbitrary (st) scale. Such values are marked in Table 1 as $m(corr)$. The measurements on blue plates (ORWO ZU–21, without filter) were carried out by using the "st" scale only, as the stars are located far from the photometric standards. The light curves are shown at Fig. 1.

The characteristics of the light curves are listed in Table 3 in the order of right ascensions: $n$ is the number of observations, max, min correspond to minimum and maximum, $< m >$ is the mean, $\sigma_O$ is the r.m.s. deviation of the data from the sample mean. The results for 3 sub–intervals of observations of TASV 0413+31 are listed separately in Table 4.

The periodogram analysis was carried out by using the program FOUR–1 by Andronov (1994). All the stars were analyzed uniformly. At first the periodogram was computed for the original observations. Results are listed in Tables 3,4: $f$ is best fit frequency, $P$ is the best fit period, $r$ is semi–amplitude, $T_{Max}$ is the initial epoch (best fit moment of maximum closest to the sample mean time of observations), $S(f)$ is corresponding value of the test function, $-\lg(Pr)$ characterize $Pr$ (the "false alarm probability", i.e. the probability of random occurence of the peak of the height more or equal than the observed) at one of the frequencies in the adopted range from 0 to 0.1 cycles/day.

Than a best sine fit was subtracted from the observations, and the periodogram was recomputed by using these "prewhitened" data. For the object TASV 0008+47 the best fit frequency is formally zero, thus the parabolic trend was subtracted from the observations. Another star TASV 0413+31 showed drastic brightness increase and thus we subdivided the data into 3 time intervals as shown at Fig. 1 with close (in time) points naively connected with lines.

The characteristics of the highest peak at the periodogram for $O - C$ are also listed in Table 3. Usually the peaks become less prominent and may correspond to a statistical noise.

### Discussion

**TASV 0008+47.** No periodicites found. The significant trend towards lower luminosity was present during our observations onto which the aperiodic variations are superimposed.

Table 1. Brightness of the comparison stars

| * | st | $m_0$ | $m(corr)$ |
|---|---|---|---|
| | TASV 0356+34 | | |
| a | 0 | 10.5 | 10.54 |
| b | 4 | 11 | 10.93 |
| c | 6.71 | 11.2 | 11.19 |
| d | 9.21 | 11.4 | 11.44 |
| | TASV 0413+31 | | |
| a | 0 | 9.1 | 9.06 |
| b | 4 | 9.6 | 9.57 |
| c | 5.88 | 9.8 | 9.81 |
| d | 8.26 | 10 | 10.12 |
| e | 9.26 | 10.3 | 10.24 |
| f | 13.39 | 10.7 | 10.78 |
| g | 14.64 | 11 | 10.93 |
| h | 18.02 | 11.4 | 11.37 |

Table 2. Brightness of the comparison stars

| * | st | * | st |
|---|---|---|---|
| *0008+47 | | *0451+69 | |
| a | 0 | g | 0 |
| b | 6.22 | i | 6.7 |
| c | 7.66 | j | 10.56 |
| d | 10.55 | *1924+57 | |
| e | 11.99 | a | 0 |
| f | 12.42 | b | 1 |
| *0714+39 | | c | 2 |
| c | 0 | d | 4.25 |
| d | 4.35 | e | 6.25 |
| e | 8.8 | f | 8.5 |
| g | 10.65 | g | 10 |
| | | h | 11.75 |

Table 3. Characteristics of the observed stars.

| star | TASV 0008+47 | TASV 0356+34 | TAV 0451+69 | NSV 02557 | TASV 0714+39 | TASV 0739+15 | TASV 1924+57 |
|---|---|---|---|---|---|---|---|
| Observer | SVR | VIM | VIM | SVR | VIM | SVR | SVR |
| $n$ | 134 | 94 | 57 | 60 | 98 | 66 | 50 |
| Max | $5.24^{st}$ | $10.68^{m}$ | $2.65^{st}$ | $8.33^{m}$ | $4.35^{st}$ | $10.20^{m}$ | $11.75^{st}$ |
| Min | $7.66^{st}$ | $11.94^{m}$ | 15.14st | $10.8^{m}$ | $9.89^{st}$ | $11.28^{m}$ | $17.16^{st}$ |
| $< m >$ | $6.84^{st}$ | $11.03^{m}$ | $8.34^{st}$ | $9.52^{m}$ | $7.0^{st}$ | $10.70^{m}$ | $13.94^{st}$ |
| $\sigma_O$ | $0.52^{st}$ | $0.15^{m}$ | $3.56^{st}$ | $0.50^{m}$ | $1.6^{st}$ | $0.22^{m}$ | $1.24^{st}$ |
| $O$ : | | | | | | | |
| $f$ | 0 | 0.00010 | 0.00413 | 0.03601 | 0.007709 | 0.011326 | 0.13913 |
| | | ± .00001 | ± .00001 | ± .00002 | ± .000005 | ± .000002 | ± .00002 |
| $P$ | $\infty$ | 9779 | 241.9 | 27.76 | 129.719 | 88.29 | 7.188 |
| | | ± 1055 | ± 0.6 | ± 0.01 | ± 0.09 | ± 0.06 | ± 0.001 |
| $r$ | — | 0.10 | 4.0 | 0.44 | 1.4 | 0.18 | 1.0 |
| | | ± 0.02 | ± 0.5 | ± 0.07 | ± 0.2 | ± 0.3 | ± 2 |
| $T_{Max}$ | — | 45976 | 45841 | 46251.8 | 39998 | 43078 | 45133.7 |
| | | ± 344 | ± 5 | ± 0.8 | ± 2 | ± 3 | ± 0.3 |
| $S(f)$ | 0.310 | 0.250 | 0.547 | 0.426 | 0.288 | 0.320 | 0.278 |
| $-\lg(Pr)$ | 7.9 | 9.8 | 6.1 | 3.8 | 3.7 | 2.0 | 0.39 |
| $O-C$ : | | | | | | | |
| $f$ | 0.06589 | 0.01609 | 0.00660 | 0.00268 | 0.003003 | 0.153781 | 0.08091 |
| | ± .00006 | ± .00001 | ± .00001 | ± .00002 | ± .000006 | ± .000008 | ± .00002 |
| $P$ | 15.17 | 62.13 | 151.6 | 372 | 333.0 | 6.5027 | 12.359 |
| | ± 0.01 | ± 0.04 | ± .3 | ± 2.26 | ± .7 | ± 0.0003 | ± 0.003 |
| $r$ | 0.20 | 0.09 | 2.3 | 0.5 | 1.1 | 0.14 | 0.8 |
| | ± 0.05 | ± 0.01 | ± .3 | ± 0.2 | ± 0.2 | ± 0.03 | ± 0.2 |
| $S(f)$ | 0.092 | 0.190 | 0.485 | 0.361 | 0.295 | 0.294 | 0.278 |
| $-\lg(Pr)$ | 0.3 | 1.4 | 4.6 | 2.4 | 3.9 | 1.4 | 0.4 |

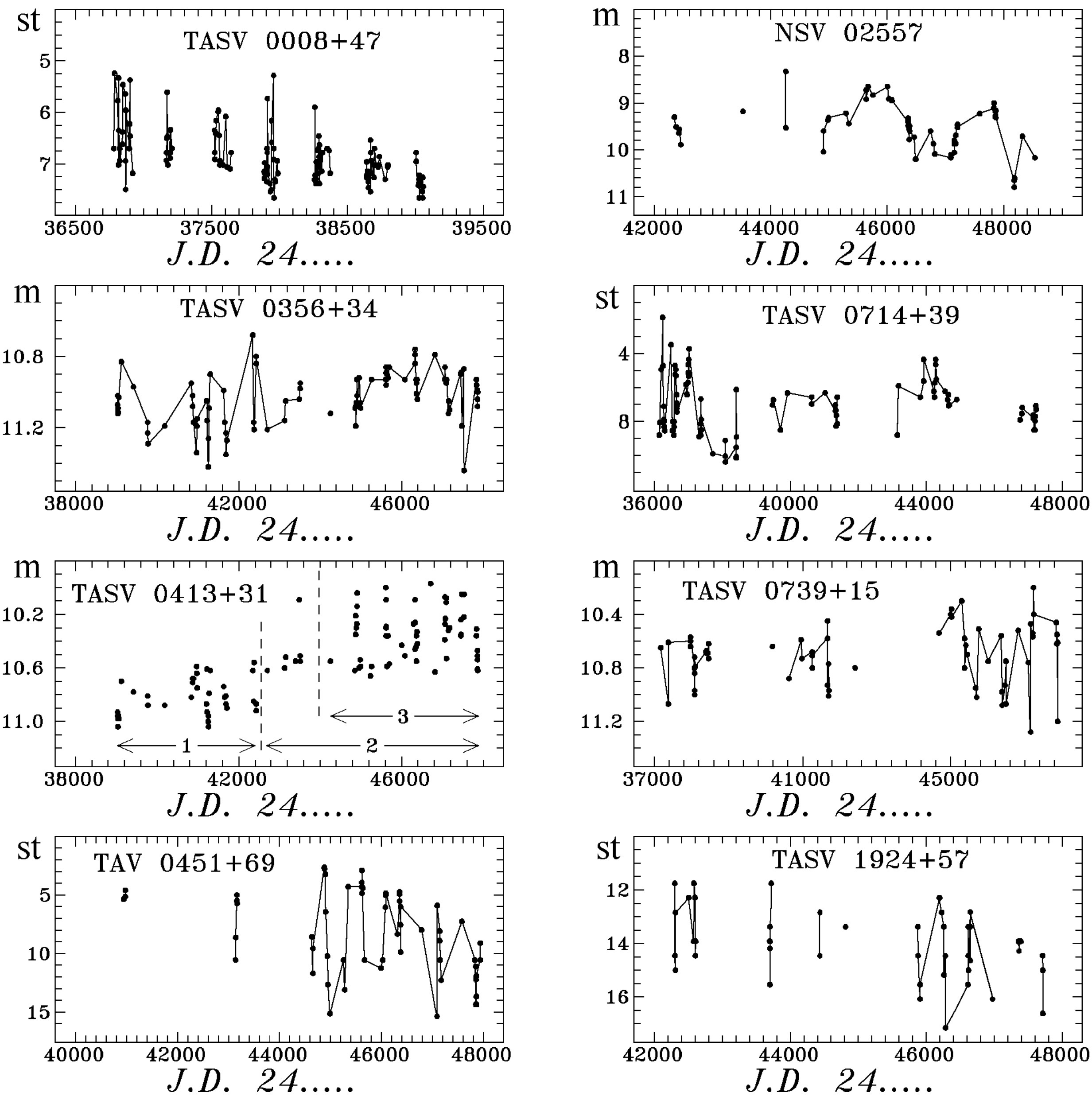


Figure 1. The light curves of the observed objects. The ordinate is in photovisual stellar magnitudes ($m$) when available or in arbitrary units ($st$). For the star TASV 0413+31 the whole interval was subdivided into 3 subintervals because of significant change of the mean brightness during our observations.

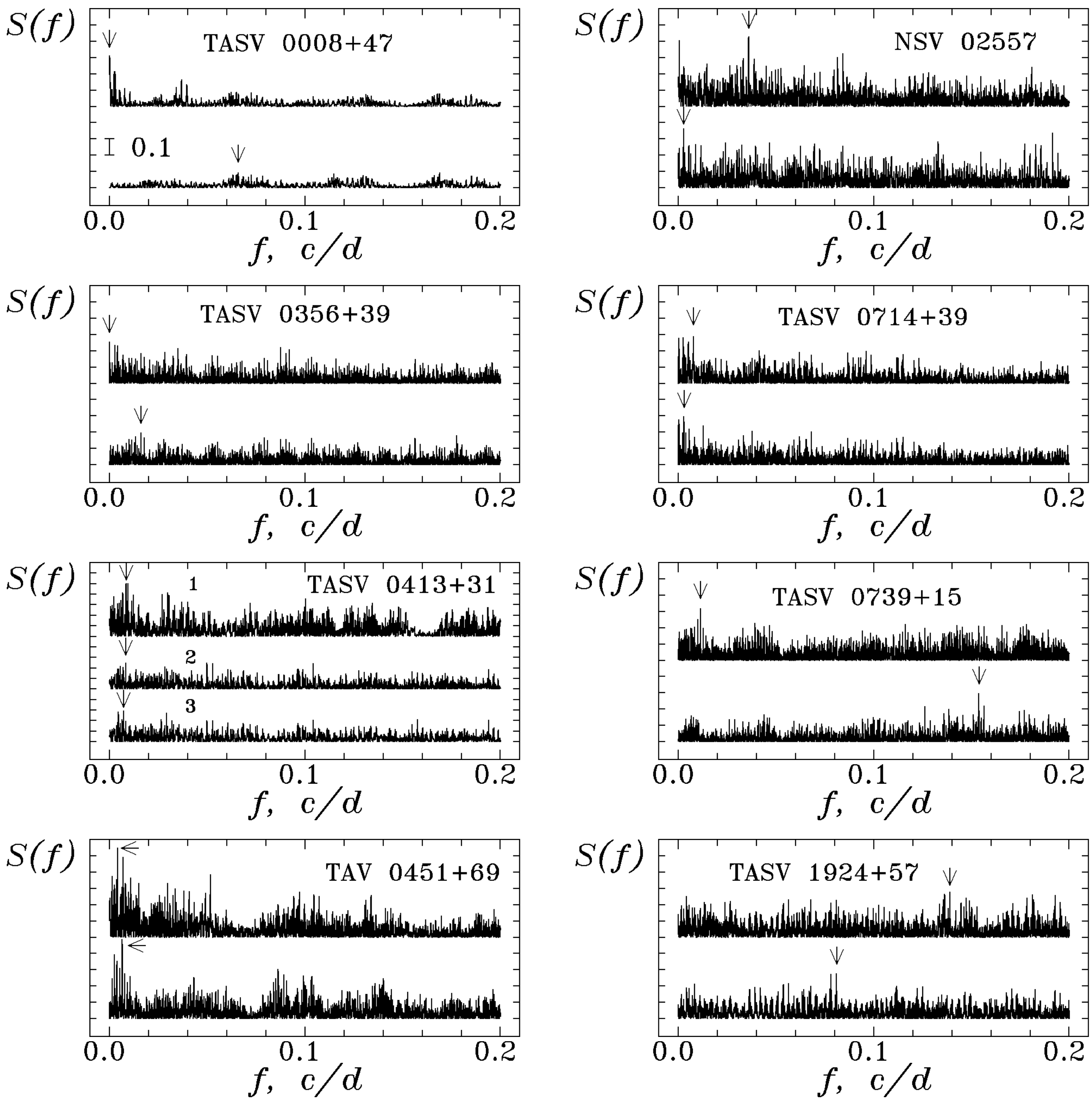


Figure 2. The periodograms $S(f)$ for the observations (up) and for the deviations $(O-C)$ (bottom of each figure) from the best sinusoidal fit. For the star TASV 0413+31 the periodograms are shown for the 3 time intervals marked at Fig. 1.

Table 4. Characteristics of the star TASV 0413+31 (Observer VIM)

| Interval | (1) | (2) | (3) |
|---|---|---|---|
| $n$ | 37 | 63 | 57 |
| Max | $10.56^m$ | $9.97^m$ | $9.97^m$ |
| Min | $11.04^m$ | $10.66^m$ | $10.63^m$ |
| $< m >$ | $10.82^m$ | $10.35^m$ | $10.34^m$ |
| $O:$ | | | |
| $\sigma_O$ | $0.13^m$ | $0.19^m$ | $0.19^m$ |
| $f$ | 0.00861 | 0.00832 | 0.00729 |
| | ± .00003 | ± .00003 | ± .00004 |
| $P$ | 116.1 | 120.1 | 137.2 |
| | ± 0.3 | ± 0.5 | ± 0.8 |
| $r$ | 0.14 | 0.13 | 0.14 |
| | ± 0.03 | ± 0.3 | ± 0.3 |
| $T_{Max}$ | 40729 | 46112 | 46422 |
| | ± 3 | ± 5 | ± 5 |
| $S(f)$ | 0.500 | 0.246 | 0.289 |
| $-\lg(Pr)$ | 2.3 | 0.7 | 1.2 |
| $O-C:$ | | | |
| $f$ | 0.13175 | 0.03198 | 0.04998 |
| | ± .00004 | ± .00003 | ± .0000 |
| $P$ | 7.589 | 31.26 | 20.01 |
| | ± 0.002 | ± 0.02 | ± 0.01 |
| $r$ | 0.08 | 0.13 | 0.12 |
| | ± 0.02 | ± 0.03 | ± 0.03 |
| $S(f)$ | 0.386 | 0.326 | 0.294 |
| $-\lg(Pr)$ | 0.8 | 2.5 | 1.6 |

**TASV 0356+34.** The $10000^d$ wave is statistically most significant. However, it may be owed to a 1 yr beat with more rapid variations. The periodogram analysis of 20 compact observations (JD 2440835–41708) shows a highest peak corresponding to $T_{Max}$ = 2441203± $3^d$, $P$ =87.9± .8, $r$ =.167± $.034^m$, $S(f)$ = 0.60. Deviation of the period value from that of $62^d$ listed in Table 3 may be owed to the cycle changes seen e.g. in the "short" interval.

**TASV 0413+31.** Significant increase of brightness by $0.6^m$ and of scatter from $0.13^m$ to $0.19^m$ occurred after JD 2442600. The whole data set was subdivided into 3 subintervals for which the periodograms were compared separately. The highest peaks appear at similar periods 116 – $137^d$, although the formal error estimates are much smaller than the difference.

**TAV 0451+69.** Böhme (1992a) confirmed variability range ($10.7^m - 14.5^m$) on photovisual plates of the Sonneberg observatory taken in 1972-1990 and classified the object as a Mira–type variable with an ephemeris $Max.JD = 2441990 + 242^d \cdot E$ The highest peak at the periodogram for our observations (Fig.2, Table 3) occurred $P = 241.9^d \pm 0.6^d$ in excellent agreement with Böhme (1992a). However, similar analysis of the residuals showed a presence of another periodicity with $P = 151.6^d \pm 0.3^d$. By using a method of differential corrections for a two–frequency model (Andronov 1994), we obtained the following fit:

$$st_{pg}(t) = \underset{\pm 30}{8.34} - \underset{\pm 38}{3.73} \cos(2\pi(t-\underset{\pm 4}{2445840})/\underset{\pm 7}{242.4}) - \underset{\pm 35}{2.33} \cos(2\pi(t-\underset{\pm 4}{2445795})/\underset{\pm 4}{151.7})$$

The highest peak at the periodogram for the residuals (O-C) from this two–frequency fit appears at $P = 11.914^d \pm 0.002^d$ with a much smaller amplitude $1.42 \pm 0.27$ which may appear due to a statistical fluctuation. Thus we confirmed main period of $242^d$, but also detected another oscillations at $151.7^d$.

**NSV 02557.** Brightness range $8.3^m - 10.8^m$ for our observations differs from that $9.4^m - 10.7^m$ of Collins (1991), indicating brightenings in our sample. The periodogram analysis shows a peak at $P = 27.76^d$ close to 1 Moon month indicating that it is possibly a beat period. Corresponding low–frequency part of the periodogram shows 2 peaks of similar height corresponding to periods 1587±29 and 1878±41 days. However, the same analysis of 47 more compact observations in the narrower range JD2444907–7865 gives fits with other periods:

$$m_{pv}(t) =$$

$$= \underset{\pm 4}{9.50^m} - \underset{\pm 6}{0.50^m} \cos(2\pi(t-\underset{\pm 5.7}{2446636.4})/\underset{\pm 2.0}{316.8})$$

and

$$\underset{\pm 3}{9.44^m} - \underset{\pm 5}{0.56^m} \cos(2\pi(t-\underset{\pm 34}{2445701})/\underset{\pm 92}{2501})$$

Corresponding r.m.s. deviations of the observations from the best fit curves are equal to

$0.26^m$ and $0.22^m$, respectively. Thus formally longer period fits observations better. Two-frequency fit shows that one of these peaks is a bias with 1 year, i.e. an alias due to the "observational window". Thus we may suggest that the real period is $P = 317^d$, but cycle-to-cycle changes of the phase curve are also present. To test possible asymmetry, we fitted the phase curve by trigonometric polynomials with different number of harmonics $m$ (Andronov 1994). For various $m \leq 8$ we obtained best fit values of $P$ from $315^d$ to $321^d$, mainly closer to $317^d$. Another wave with $P \geq 8000^d$ may also be present. The object may be classified as a semiregular variable with $P = 317^d$ during our observations. Variability at other time scales is also present.

**TASV 0714+39.** The "false alarm probability" estimate of both waves with $P_1 = 130^d$ and $333^d$ is low. The longer wave has an "1-yr" alias at $404.4^d$, i.e. $\approx 3P_1$. The multi-harmonic analysis of the same data (Andronov 1994) showed the best fit period of $P = 403.2 \pm 0.3^d$, epoch of the maximum brightness JD 2439852$\pm 3^d$. Smoothed brightness at minimum is $9.6 \pm .7^{st}$, at max $4.9 \pm .3^{st}$. Although 3 harmonics were taken into account, the fit curve is symmetrical within error estimates.

**TASV 0739+15.** The periodogram for 34 more compact observations after JD 2444686 shows a highest peak at $P = 6.052 \pm .002^d$ and an amplitude $0.24 \pm .05^m$ ($S(f) = 0.41$). The periodogram for $O - C$ shows peaks of nearly equal height at $P = 88$, 24 and $7.9^d$. The light curve argues for variations at a time scale of few (possibly 6–8 as seen at the perioogram) days, although they are not strictly periodic.

**TASV 1924+57.** Böhme (1992b) measured 202 photovisual plates of the Sonneberg Observatory and classified the object as a SRb variable with brightness variations from $10.3^m$ to $11.6^m$, cycle length from $340^d$ to $420^d$ and an amplitude varying from $0.4^m$ to $1.3^m$. From 8 moments of maxima he derived an ephemeris $Max.J.D. = 2445520 + 380 \cdot E$. Our periodogram analysis showed a highest peak apparently corresponding to much shorter time scale. The main period is not seen because of its signifiacant variability.

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