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# A CCD PHOTOMETRIC SEARCH FOR PULSATIONS IN SZ Her

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In a recent comprehensive catalogue of $\delta$ Scuti type pulsating stars there are 86 objects belonging to binary or multiple stellar systems (Rodríguez et al., 2000). Of those, only 9 stars are components of eclipsing binaries (Rodríguez & Breger, 2001). Recent surveys revealed a few more eclipsing binaries with pulsating components (e.g. Kim et al., 2003). These stars are desired compound for asteroseismology in order to identify pulsation modes through determination of fundamental physical parameters. Another interesting possibility is the study of tidal effects on oscillation (Willems & Aerts, 2002).

Inspired by this importance, we started a photometric survey of Algol-type eclipsing binaries for pulsating components. Since $\delta$ Scuti stars are main-sequence or slightly evolved A–F type stars in the lower parts of the instability strip, our targets were selected according to the spectral type of the components. Basic data were extracted primarily from the Hipparcos database (ESA 1997). In this paper we present the results obtained for SZ Herculis ($V=9\overset{m}{.}92$, $\Delta V=1\overset{m}{.}75$, mean spectral type F0V).

Photometric monitoring of this star began early (Dugan, 1923), the first visual minima are dated as back as 1902. According to light curve analysis of Giuricin & Mardirossian (1981), the system is semi-detached with a Roche-lobe filling subgiant secondary star. Cyclic O$-$C variations were noted as well (Mallama 1980, Zavala, 2002), although to our knowledge, there has not been any detailed period change study of the star.

We carried out standard Johnson–Cousins VRI filtered CCD observations on 9 nights in June and July of 2002. In order to obtain good time-resolution, the observations were single-filtered during the given night. The achieved photometric accuracy varies between 0.01–0.05 mag depending on the weather conditions. The bulk of the data was acquired with the 0.4m Cassegrain-telescope of the Szeged Observatory. This telescope was used with a cooled SBIG ST–9E CCD camera (512×512 20$\mu$m sized, 2×2 binned pixels, field of view was $6' \times 6'$). The exposure times were 30 second. One night of data was obtained with the 60/90/180 cm Schmidt-telescope of the Konkoly Observatory, equipped with a Photometrics AT200 CCD camera (1536×1024 KAF 1600 MCII coated CCD chip). The projected area is $29' \times 18'$ which corresponds to an angular resolution of $1\overset{''}{.}1$/pixel. Applying only a few second exposures – typically 5 seconds – we were able to accomplish

Table 1: Log of observations and times of minimum.

| Obs. Date | Length [h] | Telescope | Filter | $HJD_{\rm min}$ | Type | O−C (day) |
|---|---|---|---|---|---|---|
| 20.06.2002 | 5.76 | 0.4m Cass. | V | 2452446.3795(2) | primary | 0.0034 |
| 21.06.2002 | 6.48 | 0.4m Cass. | V | | | |
| 24.06.2002 | 6.24 | 0.4m Cass. | V | 2452450.4706(2) | primary | 0.0040 |
| 05.07.2002 | 6.48 | 0.4m Cass. | R | 2452461.5152(10) | secondary | 0.0043 |
| 08.07.2002 | 5.28 | 0.4m Cass. | R | 2452464.3777(3) | primary | 0.0035 |
| 10.07.2002 | 6.24 | 0.4m Cass. | I | 2452466.4207(3) | secondary | 0.0013 |
| 11.07.2002 | 6.96 | 0.4m Cass. | I | | | |
| 15.07.2002 | 7.20 | 0.4m Cass. | I | | | |
| 21.07.2002 | 4.80 | 0.6m Schmidt | I | 2452477.4705(1) | primary | 0.0068 |

relatively fast photometry thus the resulting light curve consists of more than 1600 data points. The complete dataset contains of 3 V-filtered, 2 R-filtered and 4 I-filtered nights with 5481 individual points covering 55.4 hours (see Table 1). The dataset is available at the IBVS website as `5467-t2.txt`.

For differential photometry we used the nearby stars GSC 2610–1214 (V=$11^{\rm m}\!.82$) and GSC 2610–1417 (V=$13^{\rm m}\!.11$) as comparison and check stars, respectively. We were able to determine six epochs of minimum, four primaries and two secondaries by fitting low-order polynomials to selected parts of the light curves. We list the minima in Table 1. The O−C data were calculated using the ephemeris $HJD_{\rm min} = 2434987.3959 + 0.818095693E$, while the light curve was phased with $HJD_{\rm min} = 2452446.3795+0.8180644E$. The phased instrumental light curves in V,R and I are shown in Fig. 1. The light curve is characterized by large eclipse depths ($\Delta$V=$1^{\rm m}\!.75$, $\Delta$R=$1^{\rm m}\!.62$, $\Delta$I=$1^{\rm m}\!.5$) and slight reflection effect or ellipsoidal variations of about $0^{\rm m}\!.1$.

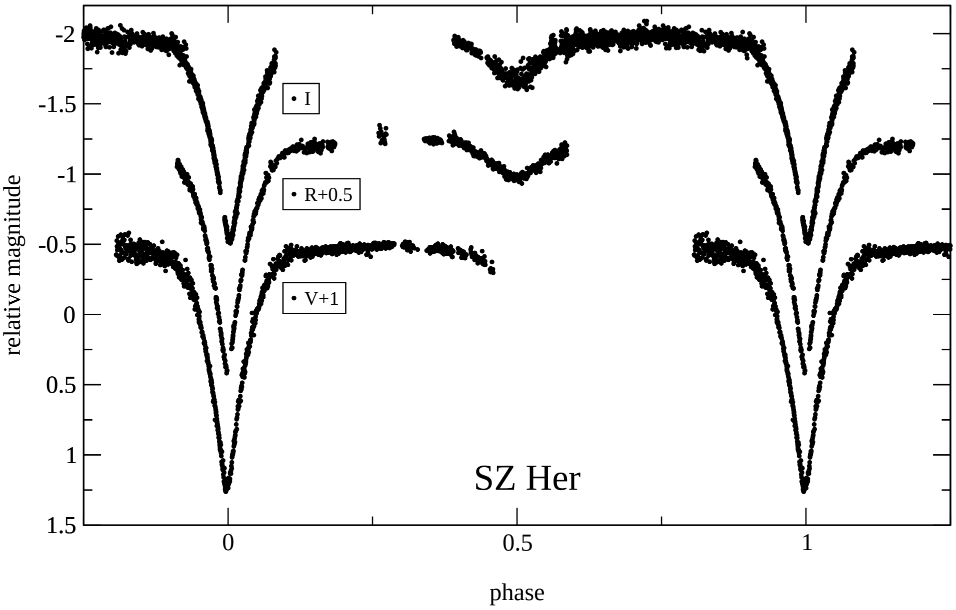

**Figure 1.** The VRI phase diagrams of SZ Her. The curves are shifted vertically for clarity.

At first sight the light curves did not show discernible light variations due to short period oscillation of any of the components. To assert more precisely the lack of short-term light variations, we performed frequency analysis of the individual light curves. For this, we calculated the binned phase diagram (the bin size was 0.01), which was transformed back to the time domain over the time span of observations. After subtracting these smooth data from the original observations, the residuals showed the deviations from the mean.

For this analyses, we used `Period98` written by Sperl (1998). The resulting Fourier spectra with the window functions are plotted in Fig. 2. We can summarize the results as follows. We could not identify any characteristic frequency produced by coherent oscillation in the residual light curves with amplitudes larger than $0\overset{m}{.}004$ in V and R and $0\overset{m}{.}007$ in I, respectively. We made simulations to estimate possible decrease of the Fourier-amplitude by the observational errors. Artificial datasets were created consisting of a low-amplitude single sine wave and different scatter levels mimicking our measurement errors. We found that the calculated amplitudes agreed very well with the initial value (within a few percent), so that our amplitude limits are only slightly affected by the noise. Thus we can certainly assert there is no $\delta$ Scuti-type pulsator in SZ Her with larger amplitudes of pulsation than these upper limits.

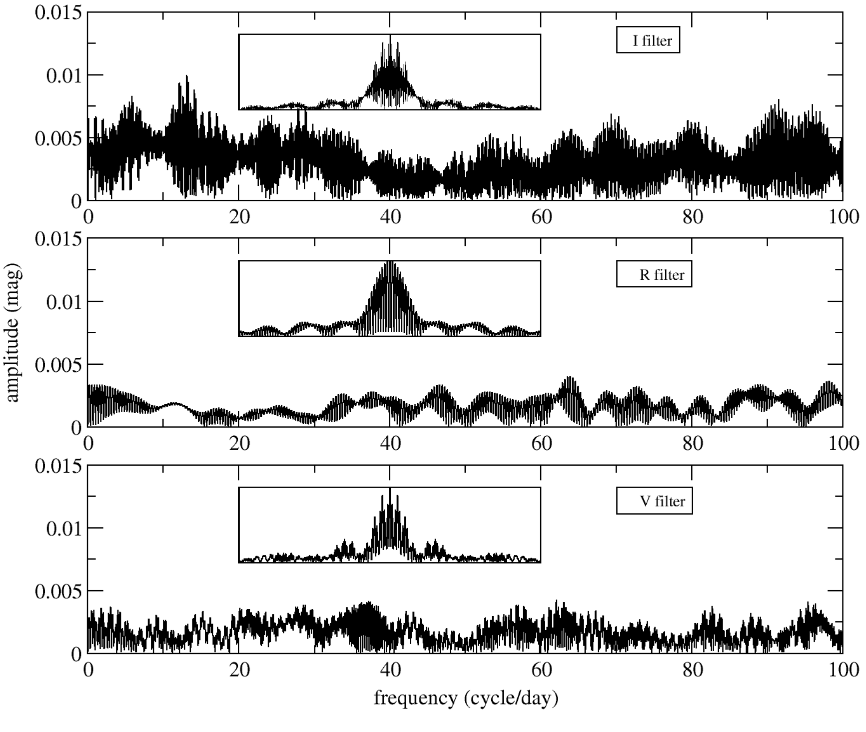

**Figure 2.** Frequency spectra of the residual light curves. The small inserts show the window functions.

In addition to this, we have checked the star's recent period change. The O−C diagram (Kreiner 2001)[1] plotted in Fig. 3 shows noticeable variations. Assuming that the changes are periodic, they can be approximated by a sine wave with $0\overset{d}{.}015$ amplitude and 66 year period.

A possible interpretation is the light-time effect produced by the binary system orbiting around a third component. Assuming these objects are orbiting approximately in the

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[1] Available electronically at `http://www.as.wsp.krakow.pl/o-c/data/getdata.php3?SZ%20her`

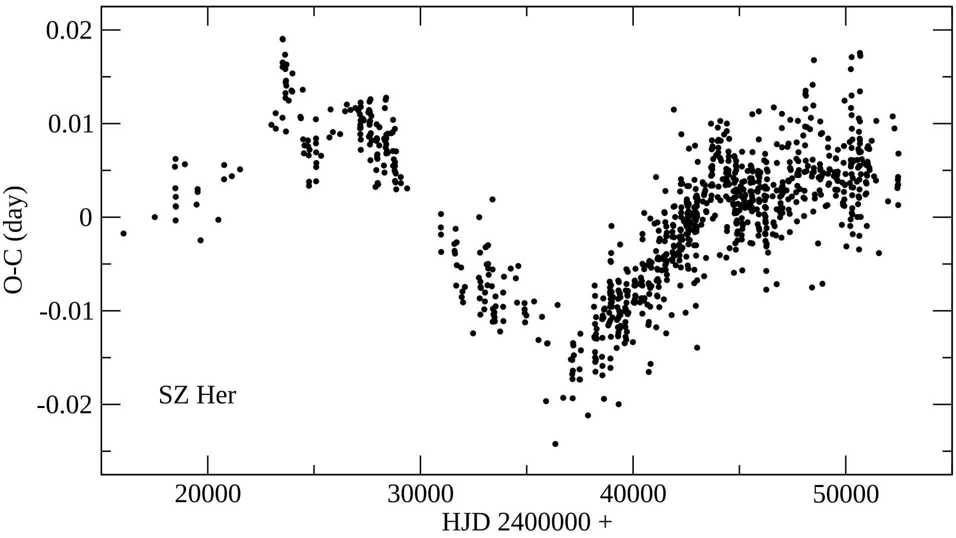

**Figure 3.** The O−C diagram of SZ Her.

same plane as the components of the binary system do (which is the usual assumption for hierarchic systems in celestial mechanics, and, consequently, the inclination is close to 90°), applying Kepler's third law, we can estimate the mass function of the third component (Zhou & Fu, 1998): $(\Delta tc)^3/P_{\rm orb}^2 = f(M_{3_{\rm min}})$, where $\Delta$t is the semi-amplitude of the O−C diagram, c is the speed of light and $P_{\rm orb}$ is the hypothetical orbital period, i.e 66 years. With parameters described above we can get $f(M_{3_{\rm min}}) = 0.004 M_\odot$. According to this, the minimum mass of the accompanying object roughly equals four Jupiters. One possibility is that the object might be a giant planet or a brown dwarf star in case of smaller inclinations.

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