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Multiwavelength research of the cyclic variability of symbiotic nova RT Ser

V. Marsakova[1], S. Shugarov[2] and I. Andronov[3]

[1] *Odesa Richelieu Science lyceum, 65082, Odesa, Ukraine (E-mail: vlada.marsakova@gmail.com)*

[2] *Astronomical Institute of the Slovak Academy of Sciences 059 60 Tatranská Lomnica, The Slovak Republic*

[3] *Odesa National Maritime University, 65029 Odesa, Ukraine*

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Abstract. For symbiotic nova RT Ser, we corrected the orbital period by using the analysis of long-term wave-like variability in B passband, the new value is 4431($\pm$22) days. When analyzing the observations in the V-band, the cycles of the variability of about 93-107 and 159 days were found, which are probably caused by the multiperiodic pulsation variability of a red giant.

Key words: stars – symbiotic – photometry

1. Introduction

RT Ser showed a symbiotic nova outburst that started in 1909 with maximal brightness in 1920 and followed by a decline in brightness and its wave-like variations after about 1970 (Payne-Gaposhkin & Gaposhkin (1938), Shugarov et al. (2003)). For the first time, the existence of an orbital period of about 10 years in this system was suspected by Pavlenko et al. (1996). Then, as the result of the analysis of photographic observations over a 40-year interval (Shugarov et al. (1997), Shugarov et al. (2003)), it was possible not only to confirm the binarity of the system but also to correct the orbital period, which was determined to be about 4500 d. In the cited paper, a preliminary model of this broad binary system was proposed.

The main parameters of the system were estimated by Murset & Nussbaumer (1994): spectral class A8 (1919-21, in outburst), with the temperature of white dwarf rising from 7500 K to over 120000 after 1980, and by Rudy et al. (1999): spectral class of the red component M5.5, distance about 5.8 kpc, E(B-V)=0.64($\pm$0.1).

2. Observations

The photometric observations were made using the telescopes of the Astronomical Institute of Slovak Academy of Science. Observations from August 2002 to

May 2012 were performed at the 50/225 cm Newton telescope (G1) with the CCD camera SBIG ST-10XME in BVRI passbands. Then (up to October 2023) at telescopes G1 and G2, but both Zeiss 60/750 cm, using cameras G4 Moravia Instrument (BVRI) or FLI-ML3041 (UBVRI). The magnitudes of comparison stars were taken from Henden & Munari (2006). The old observations in the B_{pg} and B passbands were described by Shugarov et al. (2003). In this article we will denote these close photometric systems as "B".

We used B-observations for analyzing the long-term wave-like brightness variations and our V-observations together with ones made by AAVSO observer Shawn Dvorak (DKS) for search of possible pulsation periods.

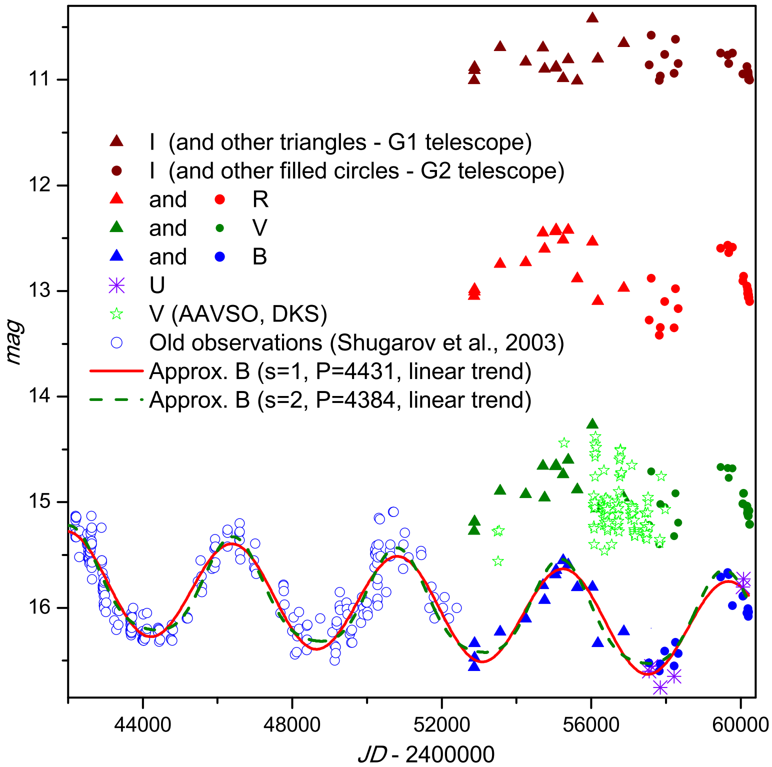

Figure 1. Observations and long-term wave-like brightness variations

3. Long-term wave-like brightness variations

Figure 1 shows wave-like brightness variations in the B passband. Similar brightness variations were observed in some symbiotic variables during the gradual decline after the symbiotic nova outburst and transition to the quiescent phase. Such effect was observed in AG Peg, V1329 Cyg, V426 Sge (Skopal

Table 1. Extrema and cycles of Long-term wave-like brightness variations

Momemts	error	cycle lengths	error
Minima			
44267	33		
48779	72	4512	79
53187	114	4408	135
57595	139	4408	180
Maxima			
46351	60		
50856	44	4505	74
55150	170	4294	176
59592	209	4442	270

et al. (2020)), PU Vul (Cúneo et al. (2018)) and other variables. According to Skopal (2001), this type of variability is caused by the optically thick part of the symbiotic nebula (ionized by the hard radiation from the white dwarf), whose contributions are different at different orbital phases. Shugarov et al. (2003) studied wave-like brightness variations of RT Ser and found the ephemeris $JD_{max} = 2446550(\pm 50) + 4520(\pm 80) \cdot E$ with a slightly asymmetrical light curve. We analyzed the observations in B passband from JD 2437846 to 2460215, totaling 288 magnitudes (one per night). Approximation with the trigonometrical polynomial of the first degree with a linear trend (Andronov (1994); Andronov (2020), realized in code of Andronov & Baklanov (2004)), gives the ephemeris

$$JD_{max,B} = 2446406(\pm 21) + 4431(\pm 22) \cdot E \tag{1}$$

We have tested hypotheses of statistical significance of higher degrees s of the trigonometrical polynomial. The false alarm probabilities (FAP), according to Fischers distributions are $15 \cdot 10^{-8}$ and 0.185 for $s = 2$ and $s = 3$, respectively. So this criterion allows us to accept $s = 2$. The trigonometrical polynomial of the second degree with linear trend gives $JD_{max,B} = 2446434(\pm 20) + 4384(\pm 19) \cdot E$.

However, the best r.m.s. accuracy of the approximation at the times of observations $0\overset{m}{.}020$ corresponds to the sinusoidal shape ($s = 1$), and increases by 12% for $s = 2$. The trend is linear during the interval of observations, the parabolic and higher degrees of the polynomial are not statistically significant. Thus we accept $s = 1$, which corresponds to the best accuracy of the approximation.

We also calculated moments of extrema during this variability in the B passband using the Asymptotic parabola method (Marsakova & Andronov (1996); Andrych et al. (2020)). Moments and cycle lengths between them are listed in Table 1. We suppose that this cycle becomes shorter with time (our value of the mean period is also shorter than one obtained by Shugarov et al. (2003))

4. Search for pulsation periods

Pavlenko (1997) suspected two periods (213 and 94 days) connected with red giant pulsations by using the observations on TV-complex, including a 50-cm telescope in BVR (1983-96). We built the periodogram (Andronov (1994); Andronov (2020)) using the joint set of our and AAVSO V-observations and also the periodogram for these series with subtracted sinusoidal 4431.4-days wave. These periodograms are shown in Fig 2. One can see the high peaks near 94, 107, and 160-day values, which could represent the pulsation cycles of the red giant. However the periodogram for our R-observations (not so numerous, but also not showing the long near orbital wave) shows the highest peaks near 170 and 156 days.

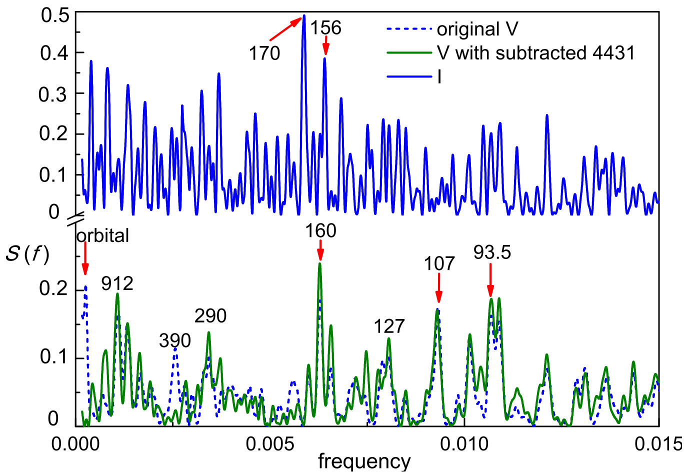

Figure 2. Periodogram for I and V-observations (initial and detrended)

We built two-periodic approximations of V-series with 93.5, 107, and 160-day secondary periods (the first period always was 4431 days). After differential corrections in these models, we obtain the more precise values 93.6 ± 0.2, 107.9 ± 0.2, 159.3 ± 0.4. The same fragment of the light curve is shown in Fig.3 with different two-periodic approximations. As one can see, 159.3^d fits well cycle near JD 2456770, but looks too long in some other time intervals. 93.6^d represents the best approximation near JD 2456300-500 but shows at least a significant phase shift in the interval after JD 2456770. The period value of 107.9^d fits well cycle near JD 2457100, but also shows phase shifts and is bad for last year's oscillations. So we can conclude that there are cyclic oscillations but they are not strictly periodic.

5. Conclusion

We corrected the ephemerid of the long-term wave and suspected that the cycle was getting shorter. We found the cyclicity from about 90 to 170 days and supposed that the pulsating variability of the red giant is not strictly periodic.

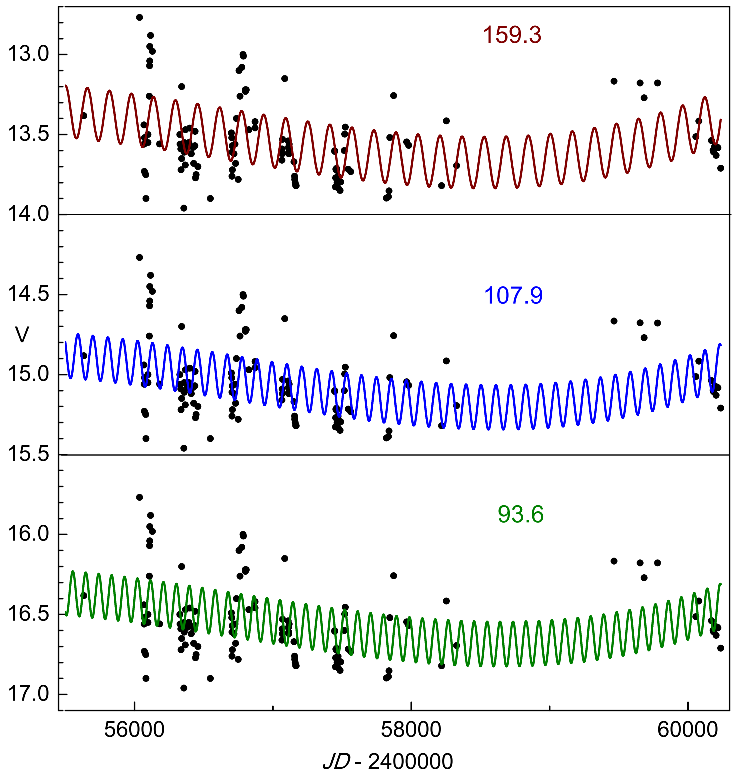

Figure 3. Two-periodic approximations of V-series with 93.6^d (shifted by 1.5^m, 107.9^d, 159.3^d (shifted by -1.5^m) secondary periods (the first period always was 4431 days)

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