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APSIDAL MOTION OF THE ECCENTRIC ECLIPSING BINARY GSC 4487-0347

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The recently discovered binary system (GSC 4487-0347, $\alpha_{2000}= 23^{\rm h}46^{\rm m}10\overset{\rm s}{.}45$, $\delta_{2000}= +71°29'55\overset{''}{.}3$, $P = 1\overset{\rm d}{.}98873$) belongs to the list of "50 new eccentric eclipsing binaries found in the ASAS, Hipparcos and NSVS databases" published by Otero et al. (2006).

We performed measurements in the B, V and R bands at the Tien Shan Astronomical Observatory using a Ritchey-Chrétien-350 telescope and an ST-402 CCD array in September-December 2009 and August-September 2011. We have only V light curve during minima.

The spectrophotometric observations were made in Barnesville near Washington using Newton-18-inch DSS-7 and ST-402 spectrophotometer.

At a distance of $3\overset{''}{.}5$ to the south of the binary star there is a neighbor fainter than the binary by $2\overset{\rm m}{.}5 \pm 0.2$. The image and the difference between stars were obtained by Menke on a clear January night. On the images obtain at the Tien Shan Observatory both stars appear as one.

The photometric elements of the system have been derived by minimizing functional depending on the measured and theoretical magnitude differences (Kozyreva & Zakharov, 2001). The model of spherical stars with linear laws of limb-darkening in eccentric orbits can be used for the analysis of the light curve.

The elements of the system are presented in Table 1. The luminosity of the nearby star is L_3. Since we did not have a sufficient phase coverage near quadratures, nor color indices throughout the whole orbit, a preliminary light curve analysis was made. We shall have more real system parameters only after measuring a better covered multicolour light curve and after more precise knowledge of the spectra of the system's stars.

Column 2 shows the solution for the 2009 light curve. All parameters except the coefficients of limb-darkening, u_1 and u_2, of the stars were free in the search. Column 3 corresponds to solution for the 2011 light curve. No reason to consider a significant change in the geometry of the binary system during the time between the two epochs of observations, the values of the parameter except ω were adopted in accordance with the results of our analysis of the most accurate 2009 light curve.

The light curve during minima is shown in Fig. 1 (2009) and in Fig. 2 (2011). The data of individual measurements are accessible on request (valq@sai.msu.ru). Given at the bottom are deviations $O-C$ of the individual measurements from the theoretical light curve as computed using the theoretical elements given in Table 1. They are shown shifted by $0\overset{m}{.}6$.

Table 1: The photometric elements of the star GSC 4487-0347, obtained from V light curve.

Element	2009-value	2011-value
r_1	0.199 ± 0.005	0.199 ± 0.005
r_2	0.151 ± 0.005	0.151 ± 0.005
i	$86\overset{\circ}{.}1 \pm 0\overset{\circ}{.}4$	$86\overset{\circ}{.}1 \pm 0\overset{\circ}{.}4$
e	0.131 ± 0.002	0.131 ± 0.002
ω	$336\overset{\circ}{.}0 \pm 0\overset{\circ}{.}3$	$340\overset{\circ}{.}5 \pm 0\overset{\circ}{.}5$
L_1	0.615 ± 0.020	0.615 ± 0.020
L_2	0.293 ± 0.020	0.293 ± 0.020
L_3	0.09 ± 0.020	0.09 ± 0.020
u_1	$0.38 \div 0.45$	$0.38 \div 0.45$
u_2	$0.38 \div 0.45$	$0.38 \div 0.45$
ϕ_{II}	$0\overset{p}{.}5762 \pm 0.0005$	$0\overset{p}{.}5786 \pm 0.0006$
J_2/J_1	0.827	0.827
L_2/L_1	0.476	0.476
σ_{O-C}	0.0082	0.0120

The B, V and R magnitudes of GSC 4487-0347 (including the optical component) with respect to the *WBVR* standard HD 222958 are given in Table 2. V magnitudes of each star are calculated using data of the luminosities (Table 1).

Table 2: The B, V and R magnitudes of GSC 4487-0347.

Stars	B	V	R
GSC 4487-0347	$11\overset{m}{.}50 \pm 0.02$	$11\overset{m}{.}19 \pm 0.01$	$11\overset{m}{.}01 \pm 0.02$
primary component	-	$11\overset{m}{.}72 \pm 0.02$	-
secondary component	-	$12\overset{m}{.}52 \pm 0.02$	-
optical component	-	$13\overset{m}{.}80 \pm 0.02$	-

In December 2010, Menke obtained spectra of GSC 4487-0347 including the optical component. SAO 10815 (A0V) was used as a comparison star. Unfortunately, the spectra have a low resolution ($\geq$ 7Å/pix) but we were able to estimate the spectral type for

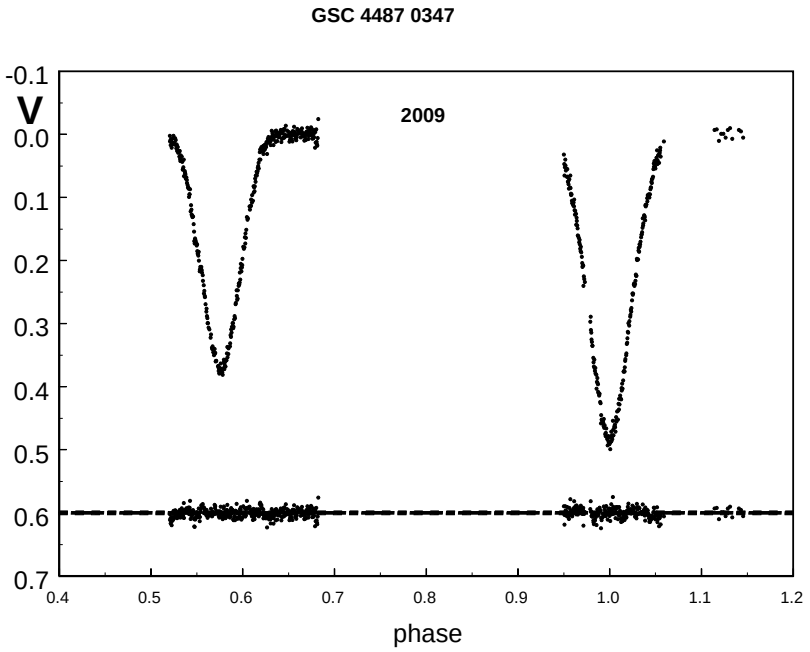

Figure 1. V light curve of GSC 4487-0347 obtained at the Tien Shan Observatory in 2009. The deviations $O-C$ are shifted by $0\overset{m}{.}6$.

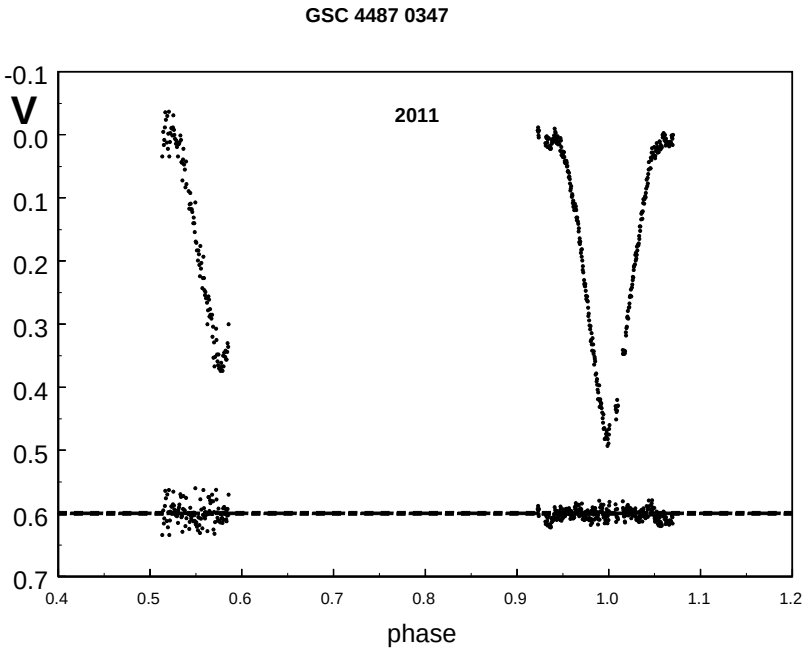

Figure 2. V light curve of GSC 4487-0347 obtained at the Tien Shan Observatory in 2011.

the components of the binary system. They are stars of B7÷A3. The coefficients of limb-darkening, u_1 and u_2, of the stars were chosen according to Van Hamme (1993) and remained constant during the calculation. We found a very weak dependence of the derived photometric elements on the coefficients of a selected range (u_1 and u_2).

The comparison of the longitude of periastron for two epochs of observation from Table 1 gives the apsidal motion:

$$\dot{\omega}_{obs} = 2.26 \pm 0.08^\circ/\text{year}; \quad U^{obs}_{apsid} = 160 \pm 6 \quad \text{years}.$$

The value of apsidal motion obtained using the data given by Otero et al. (2006) (the moment of primary minimum and the phase of the secondary minimum) does not contradict this value: $\dot{\omega}_{obs} = 2.0 \pm 0.3^\circ$/year. The same applies to the moments of minima obtained in 2008 by Kučákova and Kocián (Brát et al., 2008): $\dot{\omega}_{obs} = 2.8 \pm 1.5^\circ$/year. The moments of minima obtained in 2009 and 2011 are given in Table 3.

Table 3: The moments of minima of GSC 4487-0347.

$JD_\odot$ 2400000+	Min	2400000+	Min
55122.1578 ± 0.0005	I	55121.3150 ± 0.0005	II
55806.2827 ± 0.0005	I	55819.3656 ± 0.0008	II

The calculated ephemerides are:

$$\text{Min I} = \text{JD}_\odot\, 24\ 55122.1578(3) + 1\overset{\text{d}}{.}988731(1)\text{E}$$
$$\text{Min II} = \text{JD}_\odot\, 24\ 55121.3150(4) + 1\overset{\text{d}}{.}988751(1)\text{E}$$
$$\Delta P = P_{\text{II}} - P_{\text{I}} = 0\overset{\text{d}}{.}000020(2) = 1\overset{\text{s}}{.}73 \pm 0\overset{\text{s}}{.}20$$

The stars of the obtained spectral classes and parameters have such fast apsidal motion (2.26°/year) only on the stage of compression (Claret and Gimenez, 1993) and the theoretical apsidal motion in average is 1.5 times smaller on the later stage. We hope that the mass and accurate spectra of components will be derived, in the near future allowing us to compare the observational and theoretical values of apsidal motion.

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