NEW DETERMINATION OF PHYSICAL AND ORBITAL PARAMETERS OF 2121 SEVASTOPOL BINARY ASTEROID

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INTRODUCTION

Binary asteroids are continuously being discovered in the main belt. Characterization of these system are very important to understand and constrain the origin and evolution of our Solar System.

2121 Sevastopol is a binary asteroid from the main belt. Its binary nature was discovered from photometric observations of mutual phenomena (eclipses and occultations), which are observed on the light curves of this asteroid [1].

Within the framework of this work, an observational campaign has been organized to obtain photometric observations of mutual phenomena. Estimates of masses, density, taxonomic class as well as the preliminary orbit of the 2121 Sevastopol's satellite have been determined.

OBSERVATIONS

The observations have been conducted from June to October 2016. CCD images with standard *UBVRI* filter sets were obtained using the 0.5 m "MTM500M" telescope at Pulkovo Observatory, Russia; the 2.15 m "Jorge Sahade" telescope at CASLEO Observatory, Argentina; the 1.54 m telescope of the Estación Astronómica Bosque Alegre Observatory, Argentina; the 0.82 m telescope at Baronnies Provencales Observatory, France; the 0.3 m telescope of the Obsservatorio Astronomico – DSFTA, Universitá di Siena, Italy; and a 12" MeadeF10SCT telescope at Ngileah Observatory, New Zealand.

As the result of the observational campaign, 9 observations of mutual phenomena (eclipses and occultations) in the binary system of Sevastopol asteroid were obtained. Four of these phenomena are related to the occultations and eclipses of the satellite by the main component (the "backside" phenomenon), and other five phenomena are associated with the eclipses and occultations of the main component by the satellite (the "frontside" phenomenon). To separate the phenomena profile from the changes caused by the rotation of the main component in the light curves, all the obtained observational data were subtracted from the reference light curve obtained outside the mutual phenomena. Figure 1 shows all the profiles of mutual phenomena obtained from Jun 27 to Aug 30, 2016, as well as the reference light curve (without phenomena).

Based on the observations from Nov 11, 2016, the color index (CI) of 2121 Sevastopol has been determined:

$$B–V = 0.91 \pm 0.20$$
$$V–R = 0.49 \pm 0.10$$
$$R–I = 0.38 \pm 0.08$$

ANALYSIS AND RESULTS

Further work was related to the simulation of the binary asteroid system 2121 Sevastopol based on the obtained observational data. First of all, the density of this asteroid must be determine to estimate of masses of the components.

To determine the taxonomic class of the asteroid, we used the table from [2], which establishes a correspondence between the CI and the taxonomic classes of asteroids from the Tholen's classification [3]. The smallest differences of the spectral curve of the asteroid Sevastopol were obtained with the curves of the S (0.004) and R (0.008) classes (the sums of the squares of the differences are indicated in parentheses). The differences from the curve of C class are significantly (by an order of magnitude) larger (0.074).

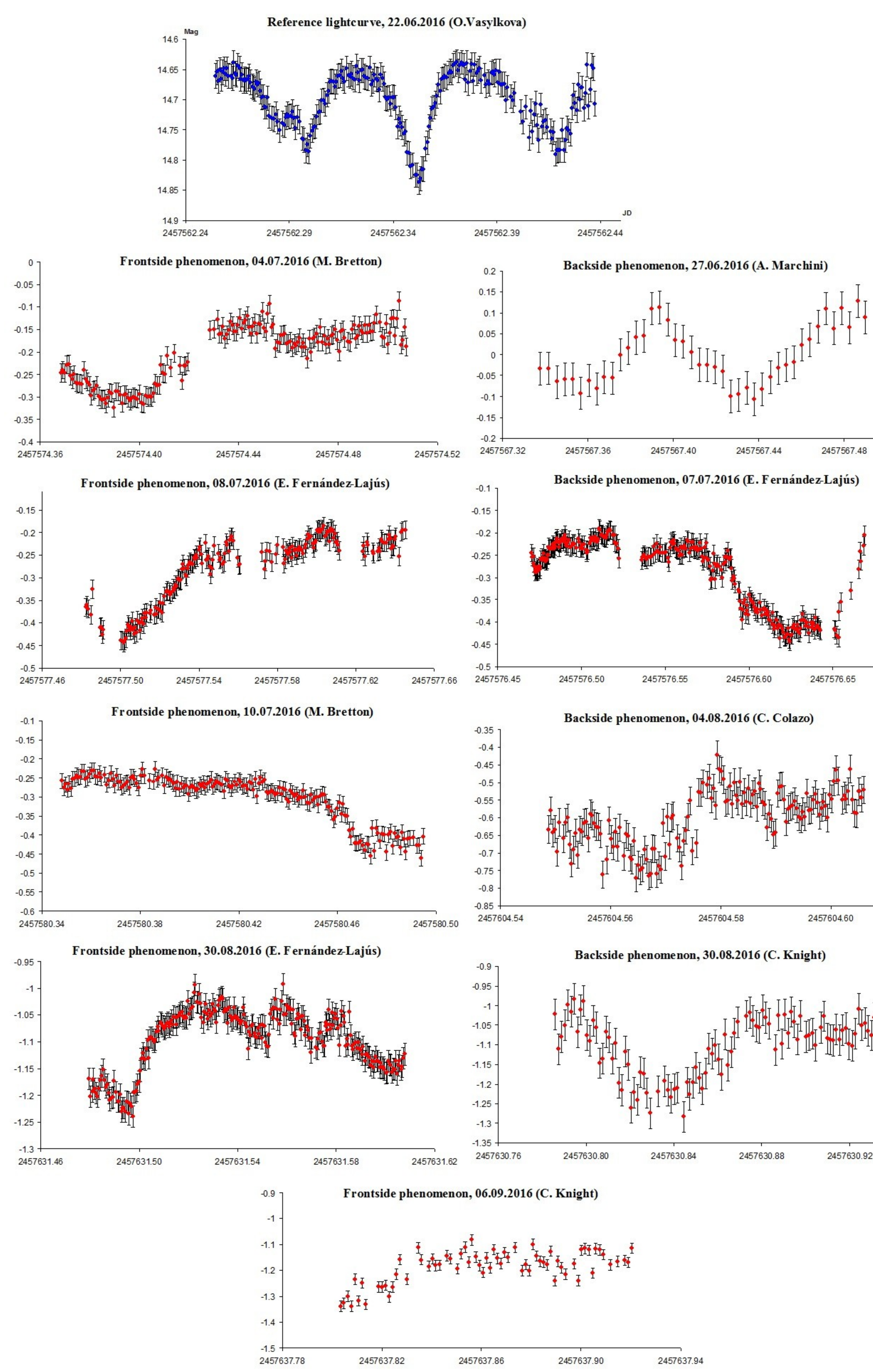

Fig.1. The reference light curve and the obtained profiles of mutual phenomena (frontside and backside).

We assumed that this asteroid is more likely to belong to the S class, which is more common for the main belt asteroids than the rare R class. The albedo is equal to 0.248 [4], which also points that this asteroid belongs to the S class. Based on the known diameter of the 2121 Sevastopol main component, D = 9.32 ± 0.04 km, knowledge of the taxonomic class allowed to estimate the density of this asteroid on the basis of the "density-taxonomic class of asteroids" dependence described in [5]. The average density of asteroids of S class is from 2 to 5 g/cm^3, with lower densities for smaller diameters [5].

The simulation of this binary system based on dynamic equations of prograde-retrograde motion [6] (equations of motion and Euler's equations) showed that the best coincidence of the model light curves with the observed at a moment of mutual phenomena is obtained with the density $\rho = 3.2 \pm 0.1$ g/cm^3. Considering the dimensions of the components known from [1,4] and NASA JPL:

Main component radius R = 4.368 km,
Satellite radius R = 1.77 km.

The masses of the components result to be:

Mass of the main component M = 1.11708 e^{15} kg,
Mass of the satellite M = 7.433 e^{13} kg.

Simulation of the light curve was carried out using the geometric positions of the Earth, the Sun, and the asteroid with the use of their ephemeris. In this case, the figures of the main component and the asteroid were divided into elementary areas using the triangulation method. For this goal we took into account a limb darkening and used three different reflection laws: Lommel-Seeliger, Lumme-Bowell and Hapke. The geometry of mutual phenomena in the binary system was calculated.

Experiments were carried out to compare the model light curves with those observed for different positions of the satellite's orbit. The results showed that the best coincidence of the observed light curves with the model curves is obtained with the following satellite orbits:

For prograde motion,
- Ecliptic coordinates: $\lambda = 323 \pm 2$ °, $\beta = 2.5 \pm 1$ °.
- Orbital period of the satellite P = 37.048 ± 0.001 h.
- The results of comparing the observations with the model are shown in Fig. 2.

For the retrograde motion,
- Ecliptic coordinates: $\lambda = 143 \pm 2$ °, $\beta = 183 \pm 2$ °.
- Orbital period of the satellite P = 37.153 ± 0.001 h.
- The results of comparing the observations with the model are shown in Fig. 3.

Figures 2 and 3 show that not all of the phenomena profiles coincide ideally. The orientation of the orbit was selected considering that the inclination of the orbit of the satellite remains unchanged. But the obtained results point to the possibly existence of small variations of the inclination of the satellite's orbit..

The simulation also showed that the main component albedo is ~ 0.05 higher than the satellite's albedo. The features of the surface relief of the main component could cause this.

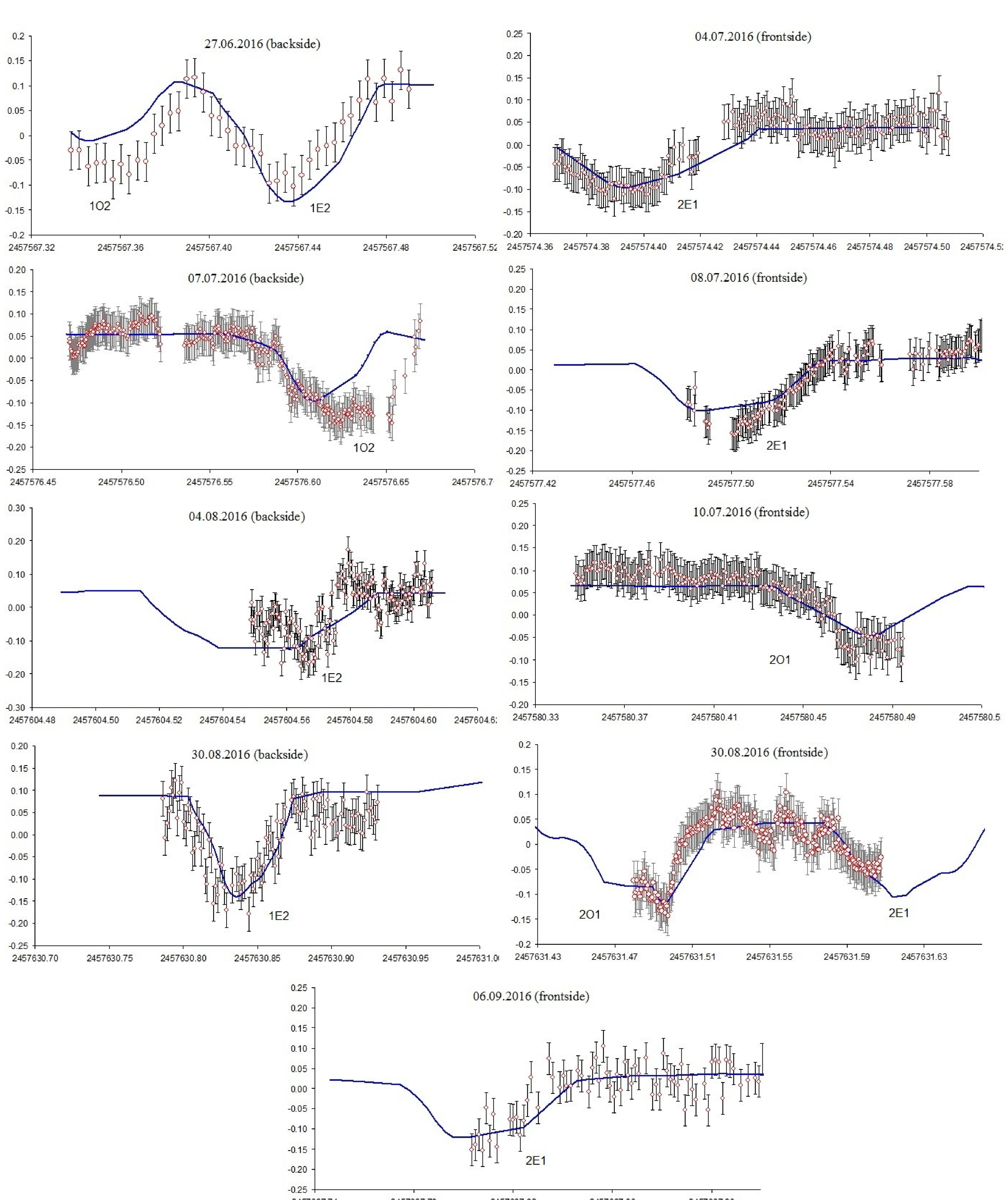

Fig.2. Comparison of the model light curves with the observed for the case of prograde satellite motion.

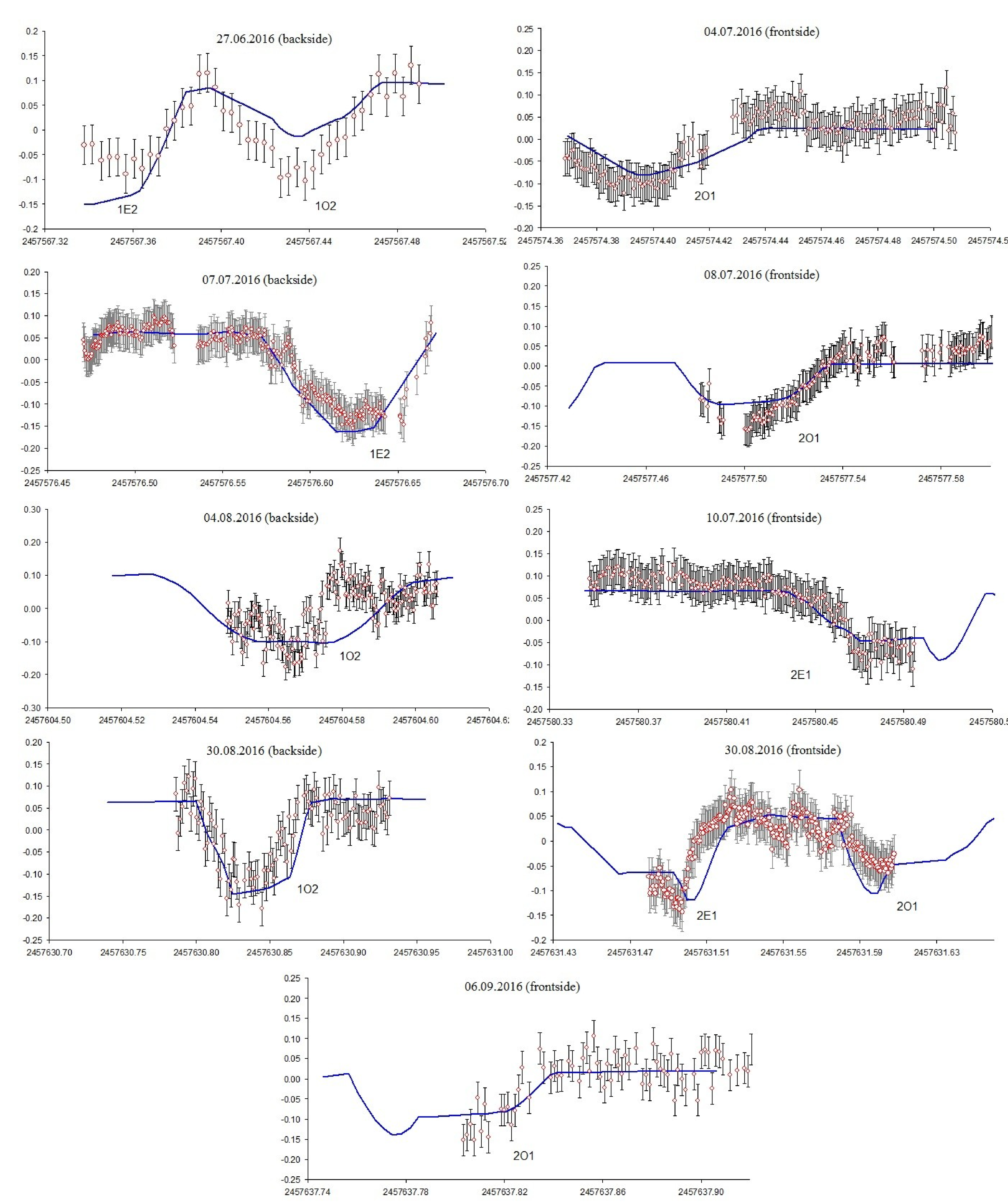

Fig.3. Comparison of the model light curves with the observed for the case of retrograde satellite motion.

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