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(Non-)detection of a quadratic drift in mean anomaly of the satellite of 1996 FG_3

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Abstract

We present an analysis of photometric observations of binary Near-Earth asteroid (175706) 1996 FG_3, observed from 1996 to 2011. The analysis gave two possible solutions for a quadratic drift of mean anomaly of the satellite, ($0.0^{+0.12}_{-0.2}$) deg/yr^2 and ~ 12 deg/yr^2. We expect to resolve between the two solutions, and to further constrain the uncertainty, using new observations obtained during 2011.

1. Introduction

A quadratic drift of mean anomaly of satellites of binary asteroids was predicted by [2],[3] as a result of the binary YORP (BYORP) effect of solar radiation pressure. The mean anomaly of changing orbit expanded to the 2nd degree in time is expressed as

$$M = n(t - t_0) + \Delta M_d (t - t_0)^2, \quad (1)$$

$$\Delta M_d = \frac{1}{2} n, \quad (2)$$

where n is the mean motion, t_0 is the time when M_0 = 0 and t is the current time. Pravec and Scheirich [7] adapted results of [2] and predicted the quadratic drift ΔM_d for several binary Near-Earth asteroids with values ranging from –0.24 to –3.27 deg/yr^2. A value predicted for 1996 FG_3 is –0.89 deg/yr^2.

Recently, Jacobson and Scheeres in [1] presented a theoretical evidence for long-term stable solution for synchronous binary asteroids. Their theory, in which mutual tides between the two components are included for the first time, would be confirmed by a lack of observed quadratic drift in the mean anomaly.

The binary nature of 1996 FG_3 was discovered by Pravec et al. [5] and by Mottola and Lahulla [4], and later reanalyzed by Scheirich and Pravec [8]. Key parameters of the mutual orbit of the two components was found to be: D_2/D_1 = 0.28 (size ratio); P_{orb}^{sid} = 16.14 h (sidereal orbital period); e ~ 0 (eccentricity); λ_p ~ 242°, β_p ~ –84° (orbital pole in ecliptic coordinates).

2. Observed data

The data used in our analysis were obtained during four apparitions: from 1996-04-09 to 1996-04-21, from 1998-12-03 to 1999-01-09, from 2009-04-12 to 2009-04-17 and from 2010-12-14 to 2011-02-09. A few examples of the data are presented in Fig. 1.

The data was reduced using standard technique described in [6]; a rotational lightcurve produced by the primary was removed in the reduction.

3. Numerical model

A numerical model used for deriving basic parameters of sizes and shapes of the two components, as well as of their mutual orbit, was described in [8]. The shapes of the components are represented as ellipsoids, orbiting each other on a Keplerian orbit, except for we included a quadratic drift of mean anomaly ΔM_d, which is fitted as independent parameter. The key to the ΔM_d determination are times of mutual events (i.e., occultations and eclipses) in the lightcurve.

4. Results

Two solutions consistent with the data were found, with the values of the quadratic drift of mean anomaly ΔM_d of $(0.0^{+0.12}_{-0.2})$ deg/yr^2 and ~ 12 deg/yr^2 (error bars of the second solution are of the same order as of the first solution). The synthetic lightcurves generated using the best-fit values of parameters for the two solutions are presented in Fig. 1.

A critical source of the ambiguity is a poor quality of the 2009 data, which do not allow us to resolve between real features in the lightcurve and possible observational artifacts, and so neither which events are occultations/eclipses of primary, and which of the secondary. Thus, both possibilities had to be tested.

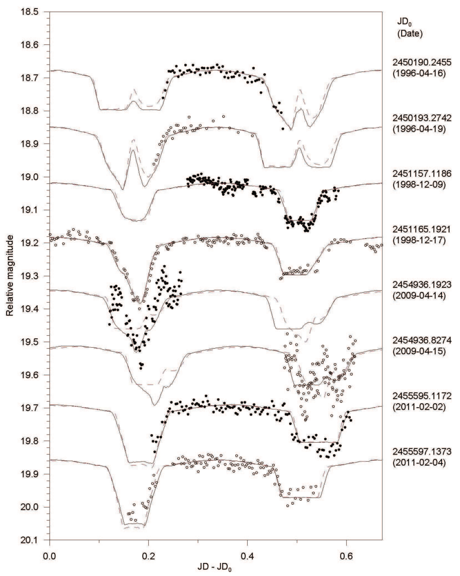

Figure 1: Examples of long-period lightcurve component of 1996 FG_3 in four apparitions. Points – the observational data. Curves – the synthetic lightcurves for the two best-fit solutions (black – ΔM_d ~ 0; red dashes – ΔM_d ~ 12)

5. Planned observations in 2011

We plan to observe the asteroid 1996 FG_3 in early July 2011 using Spitzer Space Telescope. The asteroid will be observable also in late November and December 2011 using sub-meter class ground-based telescopes. Either of these observations will enable us to resolve between the two solutions.

6. Conclusions

Our modeling of binary asteroid (175706) 1996 FG_3 can constrain theories of binary asteroids dynamical evolution. We found two solutions for the quadratic drift of the mean anomaly of the satellite, ~ 0 and ~ 12 deg/yr^2. We expect to resolve between these two solutions with additional observations during 2011.

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