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CCD Photometry of Asteroid (147) Protogeneia

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Abstract We measured the light-curve of the asteroid (147) Protogeneia in November 2004, with a CCD detector attached to the 1-meter telescope at the Yunnan Observatory, China. The synodic period and maximum amplitude of (147) at this apparition are 7.852 hours and 0.25 mag, respectively. The value of a/b for (147), from a preliminary estimation, is not less than 1.26:1.

Key words: asteroid – photometric observation – synodic period

1 INTRODUCTION

The synodic period and amplitude of light variation of an asteroid are important parameters, with which the sidereal period, sense of rotation, pole orientation, and shape of the asteroid can be deduced. These are strictly connected with the collisional evolution of the asteroid population (Binzel et al. 1989; Davis et al. 1989).

The synodic period of asteroid is the time in which the asteroid returns to the same place with respect to the earth. It varies with its relative positions to the Earth and the Sun. So precise determination of the synodic period at different apparitions is necessary.

Accurate synodic period is derived from precise photometric data, when based on precise synodic periods and light-curves obtained in different observational epochs, the determination of the sidereal period, spin vector and shape of an asteroid becomes more reliable. The main aim of this paper is to deduce the synodic period of the asteroid (147) at a new observational epoch and to make an estimation of its shape. Our observations of (147) carried out with the 1-meter telescope of the Yunnan Observatory will be described in Section 2. Section 3 presents the method of data reduction and the results of analysis. Conclusions are given in Section 4.

2 OBSERVATIONS

The asteroid (147) was discovered by Lipt Schulhof on 1875 July 10. It is a C-type asteroid of the main-belt. Our observations were made on 2004 November 2, 6, 7 and 8, with the 1-meter telescope of the Yunnan Observatory, China. All images were obtained with a CCD detector of 1024×1024 pixels and 24μm$\times24\mu$m in size, through standard Kron-Cousins r-filter. Table 1 shows the journal of observations in which the second column is the date of observation in UT; in the following columns Δ and r are the geocentric and heliocentric distances in AU; α, the phase angle and (λ, β),the ecliptic longitude and latitude in the J2000.0 reference frame; the weather condition and the photometric dispersion on the night.

3 REDUCTION AND ANALYSIS

All images were cosmic-rays eliminated, bias and flat-field corrected before they were used to measure the magnitudes. Then the magnitudes of comparison stars and the asteroid (147) were determined by using

Table 1 Journal of Observations of Asteroid (147)

Asteroid	Date (UT)	Δ (AU)	r (AU)	α (degree)	λ, β (J2000.0) (degree)	Weather	Dispersion Mag
(147)	2004/11/02.6	2.072	3.062	1.7	42.733 +17.648	slight cloud	0.016
	2004/11/06.5	2.072	3.063	0.4	41.958 +17.386	fine	0.018
	2004/11/07.5	2.072	3.063	0.5	41.757 +17.317	fine	0.006
	2004/11/08.5	2.073	3.063	0.5	41.553 +17.248	fine	0.007

APPHOT package (one of the software package of IRAF). The DAOPHOT package was also applied when the asteroid was in a crowded-field. Figure 1 shows light-curves of the asteroid (147) we obtained on four nights.

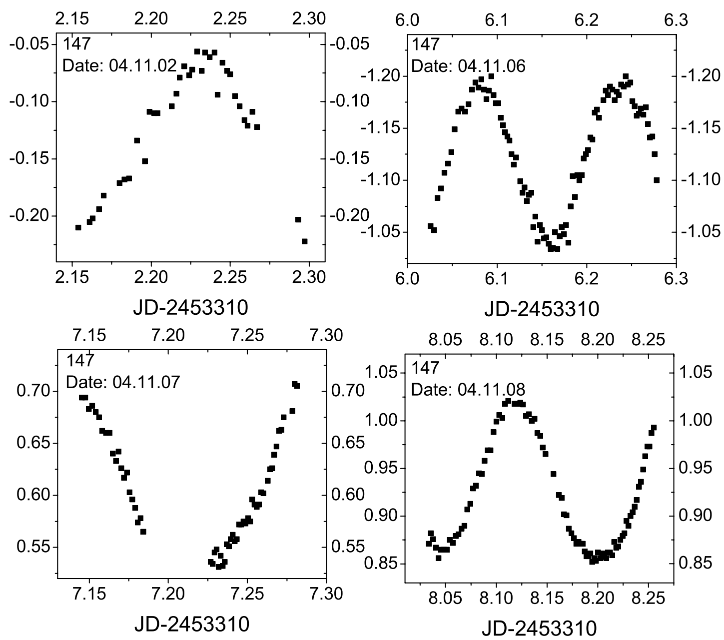

Fig. 1 Light-curves of asteroid (147) obtained by us on 2004 Nov. 2, 6, 7, 8. The ordinate is the magnitude difference between (147) and comparison star. The time is in Julian Dates.

3.1 Synodic Period

Fourier analysis was used to derive the value of synodic rotation period. Prior to the Fourier analysis, the time of observation was corrected by light-time to eliminate effect of the varying relative distance between the observer and asteroid. Time is reckoned in Julian date to combine all the observational data when they span over large intervals. The light-curves of each night were also shifted along the ΔMr axis to allow for the differing comparison stars used. The software period98 (Sperl 1998) and the PDM method (Altner et al. 1986) were applied to analyze the synodic period. For an asteroid with unknown rotation period, the PDM method does not give a unique period for short overlapping data, rather, it provides several possible values. Which one is the real period will depend on how reasonable the light-curve for the combined data (see below) is and on the scatter of the combined data at the overlapping parts.

Buchheim (2005) presented the results of asteroid (147) observed in five nights during Nov. 5–12, 2004, and gave a synodic period of 7.853 hours with an amplitude of 0.28 magnitude. Our observations were made on Nov. 2, 6, 7 and 8 of the same year. Combining our observational data with that of Buchheim (2005), a light-curve of asteroid (147) is constructed with synodic period 7.852 hours, and amplitude 0.25 magnitude. Figure 2 shows the composite light-curve.

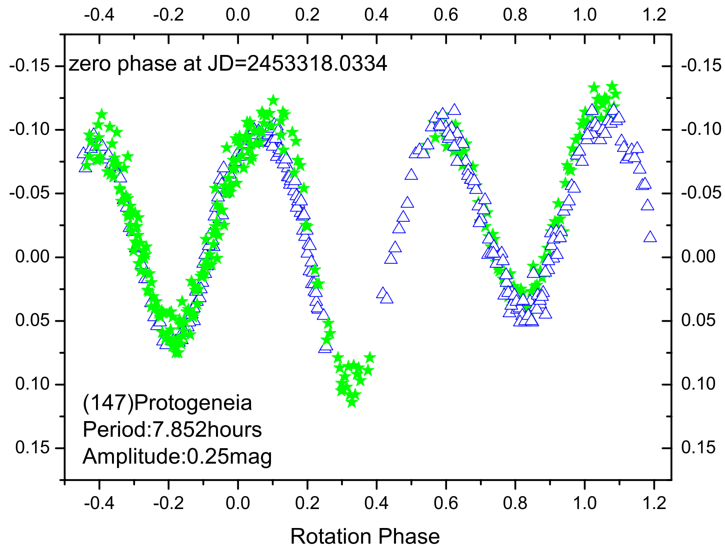

Fig. 2 Composite light-curve for our data (△) and Buchheim's data (⋆). Synodic period 7.852 hours and amplitude 0.25 mag.

3.2 Shape of Asteroid (147)

As well known, an asteroid does not shine itself and is seen by us by its reflected sunlight. Variation of the asteroid brightness is caused by differing projected areas and surface properties. If the asteroid is a triaxial ellipsoid ($a > b > c$), then the amplitude of its light-curve will be related to its shape by Equation (1), with ξ the angle between the direction of line of sight and the polar axis as seen from the center of the asteroid. A(ξ) is the amplitude at ξ (see Fig. 3, Zappala 1981).

$$A(\xi) = 1.25 \lg \frac{(c/b)^2 \sin^2 \xi + \cos^2 \xi}{(c/a)^2 \sin^2 \xi + \cos^2 \xi} . \tag{1}$$

For ξ equals 90°, we have

$$A(90°) = 2.5 \lg(a/b). \tag{2}$$

3.3 Analysis

We found that the shape of the light-curve we obtained is quite consistent with that of Buchheim (2005), especially after we supplemented the light-curve of Buchheim (2005) with the part from phase 0.4 to phase 0.6. From the light-curve we constructed we can state that a synodic period of 7.852 hours agrees with both Buchheim's data and ours.

Our composite light-curve comprises three maxima and three minima and the differences among the three minima are slight. The composite light-curve is so smooth that we deduce that the surface of asteroid (147) is uniform, while the differences among the three maxima are so apparent that we deduce the shape of asteroid (147) is irregular.

Assuming when the amplitude of light-curve reaches an extremum at 2453314.6878 (JD), we have (Fig. 2) ξ equals 90° (Eq. (2)), we deduce a value of a/b equal to 1.26:1, so we conclude preliminarily that

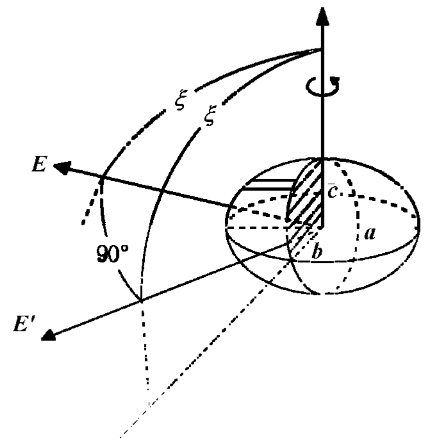

Fig. 3 Model triaxial ellipsoid (Zappala 1981).

the true value of a/b is not less than 1.26:1. Extensive observations are needed for further determination of the spin vector and shape.

4 CONCLUSIONS

We obtained a synodic period of 7.852 hours with an amplitude of 0.25 mag for asteroid (147). The synodic period we obtained turns out to be quite satisfied by the data obtained by both Buchheim and us. By combining both groups of data, we conclude preliminarily that the value of a/b for asteroid (147) is not less than 1.26:1.

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