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Determining rotation periods of NEAs from optical observations at the Terskol Observatory

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Abstract

We report photometric observations of asteroids 2005 AY28, 2007 CN26 and 2013 ET, which were obtained at the Terskol Observatory in 2013-2014 during their close approaches to the Earth. The application of different methods allowed us to estimate rotation parameters of these PHAs for the first time. Results of the light curve analysis, among others, indicated the following rotation periods: P = 6.292 ± 0.020 h for 2005 AY28, P = 6.384 ± 0.021 h for 2007 CN26, and P = 2.751 ± 0.002 h for 2013 ET.

1. Introduction

In consideration of the importance of finding and studying Earth-approaching objects, which can represent an impact hazard to our planet, one of the priorities of ground-based astronomy must be assigned to discovery and monitoring of these objects.

Starting in 1996, the facilities of the Terskol Observatory (the North Caucasus, 3100 m asl) have been heavily used for follow-up studies of comets and asteroids. Special attention is given to potentially hazardous asteroids (PHAs) because in most cases their physical characteristics are unknown. Appropriate data-analysis techniques developed have been applied to determine spectral class, relative reflectance and other parameters of asteroids [1]. Astrometric data have been routed directly to the IAU Minor Planet Center for analysis. High-accuracy photometry of asteroids has been used to study their rotation properties. In 2013-2014, complete light curves were obtained for a number of PHAs that allowed us to estimate their rotation parameters.

2. Observations and data analysis

Photometric observations of asteroids 2005 AY28, 2007 CN26 and 2013 ET were conducted with the Zeiss-600 telescope, with individual exposure times of 10-30 s. In order to enhance the signal-to-noise ratio, all CCD images were taken in “white light”.

To determine rotation parameters of the observed PHAs, we used techniques based on Fourier analysis, Lomb normalized periodogram, phase dispersion minimization (PDM), and Hotelling's T-squared statistic, respectively. Comparison of the results showed that the PDM technique and a modified version of the Hotelling test (s. Sect. 3) are most appropriate for the task.

2.1 2007 CN26

Photometric CCD data of this Apollo asteroid (D = 180-400 m) were obtained on three nights in early September 2013 - after its close approach (0.0305 AU) on August 28, 2013. Due to the ambiguous light curves of this PHA, estimation of its rotation period was rather complicated. From the light curve analysis by Hotelling's T^2 statistic, a rotation period of 3.192 ± 0.010 h was derived, with an amplitude of 0.3^m. Folding the data to the doubled period P = 6.384 ± 0.021 h (assuming a two maxima-minima model) gives a more pronounced periodicity (Figure 1).

2.2 2005 AY28

This Aten-type asteroid (D =150-330 m) made an Earth close-approach of 0.039 AU on February 7, 2014. It seems very likely that 2005 AY28 has an elongated shape: its light curves obtained at Terskol on February 3 and 5, 2014, showed that the total amplitude exceeds 1.5^m. We found a best-fit period of 6.292 ± 0.020 h using the PDM technique (Figure 2). It is essential to note that we discarded here a shorter period on the assumption of a two maxima-minima model.

2.3 2013 ET

This Apollo asteroid (D ~ 40 m) made a very close approach (2.5 lunar distances) to the Earth on March 9, 2013. Photometric observations of this PHA were performed at the Terskol Observatory shortly after its discovery, on March 6 and 7, 2013, when its V magnitude was about 15.8^m and 15.2^m, respectively.

We obtained full phase coverage (Figure 3) and found a rotation period of 2.751 ± 0.002 h, amplitude of about 0.8^m, and the *a/b* axis ratio of about 2.1. Light curve analysis was done using both the PDM technique and Hotelling's T^2 statistic; as results have shown the PDM technique provides the most acceptable solution for rotation period in this case.

3. Equations

We present the measured data u_k as a discrete model:

$$u_k = u(t_k) = f(\theta, t_k) + \varepsilon(t_k),\ k = 1,2,3,...n \quad (1)$$

where $f(\theta, t_k)$ is the signal with unknown parameter θ, ε is the vector of errors. A problem to find the spectrum from a time series with unequally-spaced data was solved in [2]. To estimate period of the signal, we use Hotelling's T^2 statistic:

$$T^2 = (n_c \tilde{\theta}_c^2 + 2n_{cs}\tilde{\theta}_c\tilde{\theta}_s + n_s\tilde{\theta}_s^2)/\tilde{\sigma}^2 \quad (2)$$

where quantities θ_k are expressed in terms of u_k and n_k are expressed in terms of t_k ; σ^2 is the error variance. The critical value is

$$T_{cr}^2 = 2F_{\alpha;2,n-2} \quad (3)$$

where F is the Fisher distribution with *2* and *n-2* degrees of freedom at the significance level α. For α = 0.005 (95%), T^2_{cr} is equal to 10.60.

As regards the current analysis, harmonics, which were significant at more than 95 %, were used to fit light curves by means of the OLS method.

4. Figures

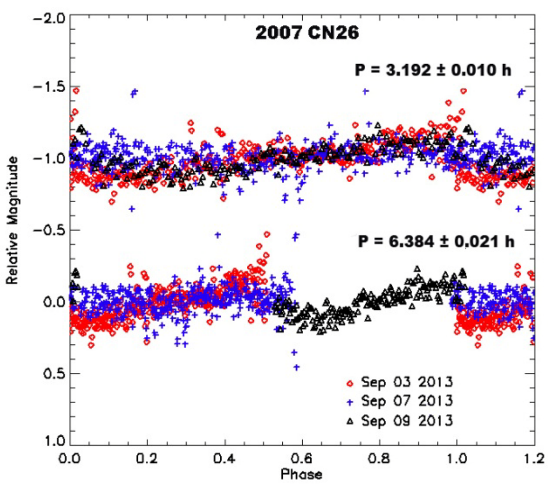

Figure 1: Composite light curves of 2007 CN26. Two possible rotation period solutions are plotted (each is shifted along the Y-axis).

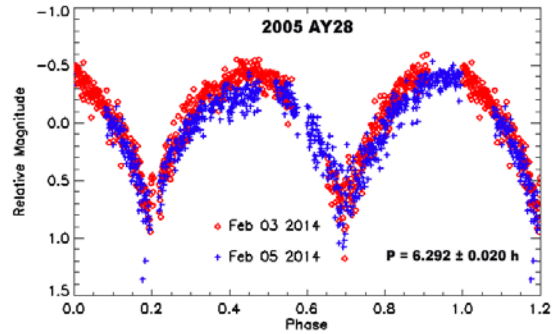

Figure 2: Composite light curve of 2005 AY28.

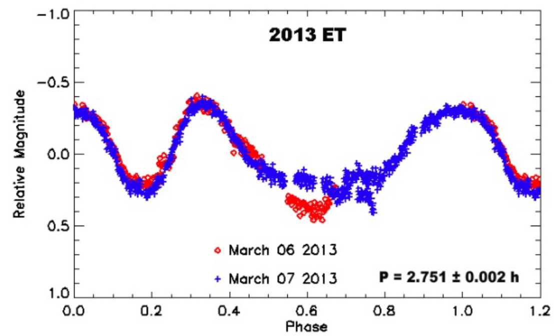

Figure 3: Composite light curve of 2013 ET.

5. Summary and Conclusions

Light curve analysis of asteroids 2005 AY28, 2007 CN26, and 2013 ET, which were observed in 2013-2014 at the Terskol Observatory, allowed us to estimate rotation parameters of these PHAs for the first time. The application of the PDM technique and Hotelling's T^2 statistic made it possible to determine rotation periods in difficult cases.

Acknowledgements

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