Investigation of the asteroids Masaakikoyama (13553) and 5131 (1990 BG) during their close approaches to the Earth

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Abstract. Astrometric and photometric observations of two near-Earth asteroids having poorly-defined axial rotation periods – Masaakikoyama (13553) and 5131 (1990 BG) – were performed using two telescopes of the Pulkovo Observatory (CAO RAS). Both asteroids in question have proved to be very slow rotators with signs of tumbling. Using the data obtained their periods were derived (97.1 ± 0.2 and 157.82 ± 0.2 hours, respectively), dense lightcurves were obtained. Accuracy of the orbital elements of the asteroids was also improved.

1. Introduction

In the frame of the study of near-Earth asteroids (NEAs) having close encounters with the other inner planets, two asteroids – Masaakikoyama (13553) and 5131 (1990 BG) – were selected from the lists "of asteroid photometry opportunities for objects reaching a favorable apparition" published in The Minor Planet Bulletin by B. D. Warner et al. [1][2]. Both asteroids had insufficiently investigated lightcurve parameters. Due to the close approaches not only near the Earth but also near the other inner planets, orbits of such asteroids as well as their axial rotation periods may change significantly. Therefore, such NEAs are of particular interest for the investigations.

The aim of this investigation was to make extensive observations of the selected asteroids during their flybys using two telescopes (ZA-320M and MTM-500M) of the Central (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences (CAO RAS), to determine the axial rotation periods of both asteroids in question using the data obtained, to obtain their dense lightcurves and to improve their orbital elements.

2. Asteroid Masaakikoyama (13553)

Asteroid Masaakikoyama (13553) was discovered by Tsutomu Seki on May 2, 1992 at Geisei Observatory, Japan. It belongs to Amor group of NEAs, its Earth minimal orbit intersection distance (Earth MOID) = 0.189213 AU and Mars MOID = 0.0533416 AU [3]. By the time of investigation, previously reported by B. D. Warner axial rotation period was determined to be 58.0 hours [4]. Masaakikoyama (13553) was on the list of Goldstone radar targets, but was cancelled [5].
3. Asteroid 5131 (1990 BG)
Asteroid 5131 (1990 BG) was discovered by Eleanor F. Helin and Brian P. Roman on January 21, 1990 at Palomar Observatory, USA. It is a member of the Apollo class of NEAs, its Earth MOID = 0.274649 AU, Mars MOID = 0.0140454 AU, Venus MOID = 0.0018736 AU [6]. On the NASA JPL website, by the time of investigation rotational period previously found by B. D. Warner was 37.2 hours with a note that "result based on less than full coverage, so that the period may be wrong by 30 percent or so" [7].

4. Photometric study
Observations of both NEAs were recorded using two telescopes of CAO RAS. Telescope ZA-320M ($D = 320$ mm, $F = 3200$ mm) is located at Pulkovo Observatory (near St. Petersburg, Russia). Telescope MTM-500M ($D = 500$ mm, $F = 4100$ mm) is located at the Mountain Astronomical Station of CAO RAS (near Kislovodsk, Russia). Both telescopes are equipped with SBIG CCD cameras.

APEX-II software package [8] was used for processing the photometric data. In the process of the photometrical reduction, 2MASS was used. Period analysis was done using the Scargle method [9], analysis of the lightcurves showed that both asteroids exhibit signs of non-principle axis rotation (tumbling).

From August 1 to September 28, 2018, 42 observation sessions of the asteroid Masaakikoyama (13553) were made and a total of 2923 data points was used for the construction of its lightcurve (figure 1). The derived axial rotation period is $97.1 \pm 0.2$ hours with amplitude of $1.0 \pm 0.1$ mag. It does not match with the previously reported period (58.0 hours). It was not possible to get a full coverage of the lightcurve and hard to determine the rotational period of the asteroid using only the data obtained due to commensurability of the axial rotation period with nearly 4 Earth's rotations.

From January 12 to March 15, 2019, 37 observation sessions of 5131 (1990 BG) were carried out and as a result a total of 1241 data points was used for construction of its lightcurve (figure 2). For 5131 (1990 BG), the derived axial rotation period is $157.82 \pm 0.2$ hours (which also doesn’t match with the previously published period of 37.2 hours) with an amplitude of $0.7 \pm 0.1$ mag.

![Figure 1. Phased lightcurve of the asteroid Masaakikoyama (13553).](image)
5. Astrometric study

EPOS [10] and APEX-II [9] software systems were used to process the astrometric data. UCAC4 was used as the reference star catalogue.

2923 data points of the observational data obtained and 1216 from IAU Minor Planet Center (MPC) website were used for the improvement of the orbital elements of Masaakikoyama (13553). Initial root mean square (RMS) = 0”.707, improved RMS = 0”.116.

464 data points selected from the observational data obtained and 1071 data points from MPC website were used for the improvement of the orbital elements of 5131 (1990 BG). Initial RMS = 0”.801, improved RMS = 0”.146

Orbital elements of the both asteroids are in good agreement with the MPCORB catalogue.

The results of improvement of orbital elements of the objects in question are shown in table 1 and table 2.

**Figure 2.** Phased lightcurve of the asteroid 5131 (1990 BG).

**Table 1.** Improvement of Masaakikoyama (13553) orbital elements for the epoch JD2458600.5.

| Elements | MPC        | Improved    | Δ         |
|----------|------------|-------------|-----------|
| $M_c$ (°) | 84.52854   | 84.52851    | −0.00003  |
| $\omega$, (°) | 109.91655 | 109.91657   | 0.00002   |
| $\Omega$, (°) | 193.49940 | 193.49935   | −0.00005  |
| $i$, (°) | 5.87434    | 5.87433     | −0.00001  |
| $e$     | 0.4639282  | 0.4639284   | 0.0000002 |
| $a$, (AU) | 2.18933550 | 2.18933621  | −0.0000071|
| $q$, (AU) | 1.17364102 | 1.17364094  |           |
Table 2. Improvement of 5131 (1990 BG) orbital elements for the epoch JD2458600.5.

| Elements   | MPC        | Improved   | Δ          |
|------------|------------|------------|------------|
| $M$, (°)   | 349.98645  | 349.98631  | -0.00014   |
| $\omega$, (°) | 135.83923  | 135.83921  | -0.00002   |
| $\Omega$, (°) | 110.37799  | 110.37802  | 0.0003     |
| $i$, (°)   | 36.42960   | 36.42971   | 0.0011     |
| $e$        | 0.5692782  | 0.5692780  | -0.0000002 |
| $a$, (AU)  | 1.48609280 | 1.48609469 | 0.0000189  |
| $q$, (AU)  | 0.64009257 | 0.64009357 |            |

Where: $M$ — the mean anomaly; $\omega$ — the argument of perihelion; $\Omega$ — the ascending node; $i$ — the inclination; $e$ — the eccentricity; $a$ — the semi-major axis; $q$ — the perihelion distance; $\Delta$ — the differences.

6. Conclusion
In this study, astrometric and photometric observations of two NEAs (that also have close approaches near other inner planets) were carried out during their flybys using two telescopes of CAO RAS.

Based on the data acquired, relatively dense lightcurves were obtained, the amplitudes were measured and the axial rotation periods of both objects in question were derived. Both derived periods do not match with the periods previously found. For Masaakikoyama (13553) it is 97.1 ± 0.2 hours with an amplitude of 1.0 ± 0.1 mag and for 5131 (1990 BG) it is 157.82 ± 0.2 hours with an amplitude of 0.7 ± 0.1 mag. The lightcurves analysis showed that both asteroids exhibit signs of tumbling.

Significant improvement of the orbital elements of the asteroids was made.

Further investigations of the given asteroids with involvement of more data are planned.

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References
[1] Warner B D, Harris A W, Šurech J and Benner L A M 2018 Lightcurve photometry opportunities: 2018 July-September Minor Planet Bull. 45(3) 304–9
[2] Warner B D, Harris A W, Šurech J and Benner L A M 2018 Lightcurve photometry opportunities: 2019 January-March Minor Planet Bull. 46(1) 100–5
[3] http://www.minorplanetcenter.net/db_search/show_object?object_id=13553
[4] https://ssd.jpl.nasa.gov/sbdb.cgi?ssr=13553
[5] https://echo.jpl.nasa.gov/asteroids/goldstone_asteroid_schedule.html
[6] http://www.minorplanetcenter.net/db_search/show_object?object_id=5131
[7] https://ssd.jpl.nasa.gov/sbdb.cgi?ssr=5131
[8] Devyatkin A V, Gorshanov D L, Kouprianov V V and Vereshchagina I A 2010 Apex I and Apex II Software Packages for the Reduction of Astronomical CCD Observations Sol. Syst. Res. 44(1) 68–80
[9] Scargle J D 1982 Studies in Astronomical Time Series Analysis. II. Statistical Aspects of Spectral Analysis of Unevenly Spaced Data Astrophys. J. 263 835–53
[10] L'vov V N and Tsekmeister S D 2012 The use of the EPOS software package for research of the Solar System objects Sol. Syst. Res. 46(2) 177–9