Rotational periods of small NEAs with close approaches

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Abstract

We present lightcurves of six fast-rotators Near Earth Asteroids (NEAs), with observations made from 3 observatories from Romania. We found very fast rotational periods and tumbling states for 2020 GF2 and 2020 UA (0.019 and 0.044 h respectively). For 2018 GE3 and 2019 GT3 we found small rotational periods (0.304 and 0.3547 h respectively) and large amplitudes. The observed asteroids fill some points in the low diameter (uncharted territory) part of the Frequency/Period vs. Diameter diagram for asteroids.

Background

Finding asteroidal rotations is a topic that is still relevant in planetology. Photometry, the method used in determining rotational properties as rotational period, amplitude of brightness variation, pole orientation and shape, allowed the charaterization of over almost 30 000 asteroids (1) of which over 1700 are Near Earth Objects (NEA).

TThere seems to be a correlation between the internal strucutre of the asteroids and their rotation. A rotational barrier for objects larger than a few hundred meters has ben discovered (2) and also that monolithic fast rotators tend to be abundant in small object population (3). The spin barrier dissapears for smaller objects, which rotate too fast to be held only by self-gravitation (3).

The frequency/period vs. diameter diagram is a useful tool for the study of asteroidal rotation, as it shows that small NEAs have fast rotation rates. A special region of the diagram is the low diameter territory, where asteroids have rotations faster than 10 rotations per day and diameters smaller than 100 meters. The distribution of rotations of small objects does not follow a Maxwellian fit (2), which implies the presence of non-gravitational forces (YORP effect) that accelerate or decelerate the rotational speed. The need of more data points is obvious, but small NEAs can be observed for a short period of time during a close approach, time in which the phase angle changes rapidly and also the observing geometry. Our observations provide more rotational data for small NEAs.

Observations

During our routine NEAs observations, to confirm newly discovered and small NEAs, we also monitored them for brightness changes. For our observing program we use telescopes in the range of 0.4-0.6 m in diameter located in Romania. From Bucharest Observatory (MPC code 073) we observed the asteroid 2018 GE3; from Cluj-Napoca Observatory we observed 2020 UA; form Berthelot Observatory (MPC code L54) (4) we observed 2019 GT3, 2020 GA2, 2020 FG2, 2020 UA and 2021 AU.

We used two SBIG STL-11000M CCD cameras, cooled down to −20° C. The field-of-view is 44x29 arcmin and the pixel scale of 1.3"/pixel (L54 and 073) and 0.9"/pixel (Cluj-Napoca). 2x2 binning was used during image aquisition, in order to minimise image download time from sensor. In order to maximise signal to noise ratio (SNR) no filter was used in any of our observations.

The raw images were calibrated with bias, flats, and darks using the standard procedures of MaximDL software (http://diffractionlimited.com/product/maxim-dl/). Our images were processed with MPO Canopus software (http://www.minorplanetobserver.com/MPOSoftware/MPOCanopus.htm). Differential photometric measurements were performed using the CompStar Selector (CSS) procedure in MPO Canopus, which allows selecting up to five reference stars with near solar color. For every observing session we used at least 3 reference stars, with magnitudes taken from the APASS DR9 catalogue (5). For most objects we used differential tracking at half speed of the asteroid. For every object the visual field changed frequently, toghether with the reference stars, and some small adjustments to the zero-points of the sessions were made in order to minimize the overal RMS fits of the lightcurves.

The period analysis was performed using Tycho-Tracker software (https://www.tycho-tracker.com), which uses the FALC (Fourier Analysis for Lightcurves) algorithm (6). The rotational period was determined by applying Fourier analysis on our observational data.

Results

2018 GE3

The near-Earth asteroid (NEA) 2018 GE3 was discovered 2018 April 11 (JPL, 2018). It made its closest approach to Earth (193.000 km) on Apr 15 at 06:41 UT. The asteroid was observed when it was at 0.005 AU from Earth. Our data fit a period of 0.304 ± 0.0098 h. The lightcurve amplitude is 0.95 mag. A fourth-order fit showed an asymmetric bimodal lightcurve.

2019 GT3

This asteroid was observed on the outbund leg, on Sept 9, 2019, at 0.05734 AU from the Earth. Our data show a light curve with unequal brightness minima and maxima. The rotational period is 0.3547 ± 0.0098 h and the amplitude is 0.72 mag. The asteroid was also observed by Pravec et al. (7) who found a similar period.

2020 GF2

The asteroid was observed during one night on the inbound leg, at 0.00679 AU from the Earth, 6 hours before the closest approach. The light curve has uneven minima. The rotational period is 0.0186 ± 0.0004 h and the amplitude 0.55 magnitudes. The individual points on the light curve have a large scatter in magnitude, which implies a tumbling state with a variable amplitude.

2021 AU

It was observed 1 day before closest approach, on the night of 05/05 Jan 2021, at 0.0113 AU from the Earth. The rotational period is 1.6635 ± 0.019 hours and the amplitude 0.79 magnitudes.

2020 GA2

The asteroid was observed on the night of 12/13 Apr 2020, at 0.0289 AU from the Earth. The light curve shows a large scatter in magnitudes. The rotational period is 0.1209 ± 0.0097 hours and the amplitude 0.35 magnitudes.

2020 UA

We observed this asteroid on the night of 20/21 Oct. 2020, for 30 minutes, starting with 20:30 UT, from Cluj-Napoca Observatory, and for 36 minutes starting at 22:24 UT, from Berthelot Observatory (8). We found that the lightcurve form Berthelot and Cluj-Napoca could not be fitted with the same period, although we could find a common period for sessions from the same observatory. For Berthelot we found a period of 0.0293 ± 0.0002 h with an amplitude of the Fourier fit of 0.47 mag. We mention that the real amplitude is variable from one cycle of rotation to another. For Cluj-Napoca data we found a rotational period of 0.0440 ± 0.0006 h with an amplitude of 0.61 mag.

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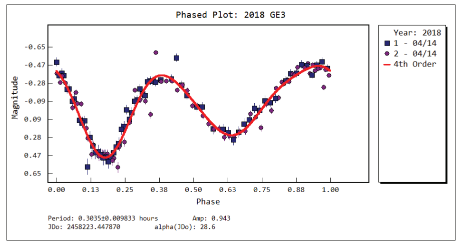
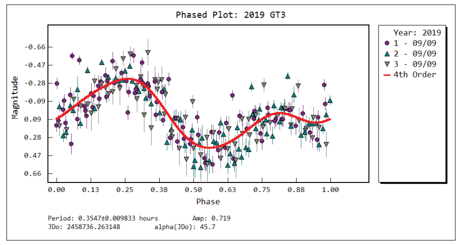
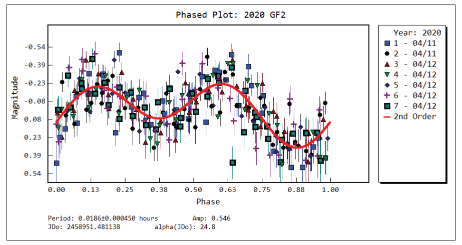
2 Pravec, Petr, Alan W. Harris, and B. D. Warner. "NEA rotations and binaries." Proceedings of the International Astronomical Union 2.S236 (2006): 167-176.
3 Pravec, Petr, and Alan W. Harris. "Fast and slow rotation of asteroids." Icarus 148.1 (2000): 12-20.
4 Birlan, M et al. Berthelot, the new astronomical station in Romania, Romanian Astronomical Journal, Vol. 31, No. 1, p. 41-56, 2021
5 Henden, A.A., Templeton, M., Terrell, D., Smith, T.C., Levine, S., Welch, D.: 2016, VizieR OnlineData Catalog: AAVSO Photometric All Sky Survey (APASS) DR9 (Henden+, 2016).VizieR OnlineData Catalog 2336
6 Harris, A.W., Young, J.W., Bowell, E., Martin, L.J., Millis, R.L., Poutanen, M., Scaltriti, F., Zappala,V., Schober, H.J., Debehogne, H., Zeigler, K.W.: 1989, Photoelectric observations of asteroids 3,24, 60, 261, and 863.Icarus77, 171 – 186.
7 Pravec, P.; Wolf, M.; Sarounova, L. (2019) http://www.asu.cas.cz/~ppravec/neo.htm
8 Sonka, Adrian Bruno, et al. "Fast Rotator Minor Planet 2020 UA From Cluj and Berthelot Observatory." Minor Planet Bulletin 48.2 (2021): 100-101.

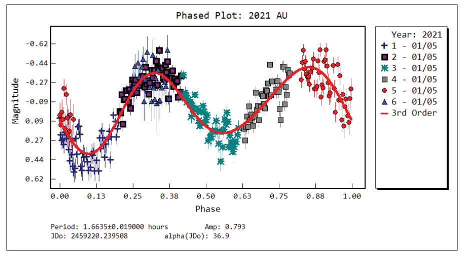
Lightcurves

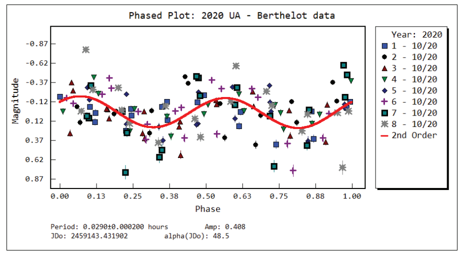
For each asteroid we present the phased folded lightcurve, together with data points for every day of observations. A fourier fit is superimposed on the data. For asteroid 2020 UA we present separately the data from Berthelot and Cluj-Napoca observatories, as we found two different rotational periods.

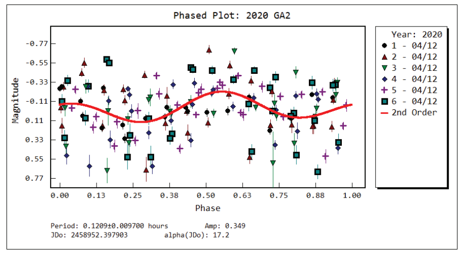


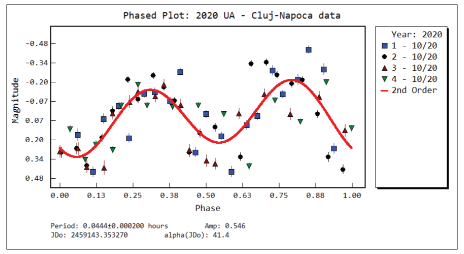






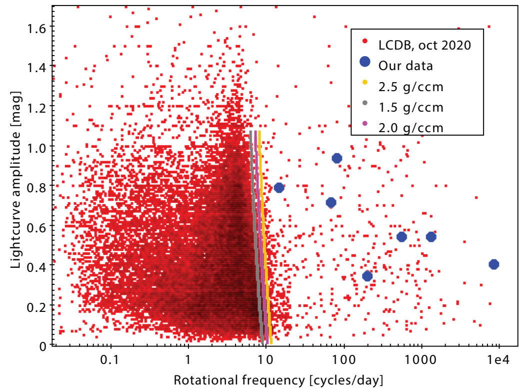






Rotational frequency vs. the amplitude of the lightcurve

The limits of rotation for asteroids with densities of 1.5, 2.0 and 2.5 g/ccm are plotted. Our data show that the asteroids studied are beyond the rotational breakup limit, which implies a rotation beyond a gravity regime. Data from The Asteroid Lightcurve Database (6) is plotted.



Absolute magnitude vs. Rotational frequency

Asteroid rotations show a clear spin barrier at 2.4 cycles/day for large objects. For small asteroids the break up limit disappears as we encounter monolithic objects which rotate so fast that their simple gravity is not enough to keep their shape. The cohesion of the particles allows fast rotations for small asteroids, as are the ones we observed.