Study of fast and slowly rotating near-Earth asteroids: 2023 DZ2 and 96590 (1998 XB)

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Within the framework of the Pulkovo program for studying near-Earth objects and the problem of asteroid and comet hazard, two near-Earth asteroids, 2023 DZ2 and 96590 (1998 XB), with axial rotation periods of 360 and $1.872 \cdot 10^6$ s, respectively, were studied, which represents a very fast and extremely slow rotation. The orbital evolution of these objects, the circumstances of their close encounters, and the influence of non-gravitational effects were studied. Based on the obtained observational data, it was possible to determine the period of axial rotation of asteroid 2023 DZ2.

Keywords: near-Earth asteroids, orbital evolution, non-gravitational effects.

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As part of „Pulkovo Program for the study of near-Earth Objects" [1] and in connection with the problem of asteroid and comet hazard, two near-Earth asteroids, 2023 DZ2 and 96590 (1998 XB), with periods of axial rotation 360 s (6 min) and $1.872 \cdot 10^6$ s (21.6 days), respectively, were studied at the Laboratory of Observational Astrometry of Pulkovo Observatory. So far, there have been discovered about $1.3 \cdot 10^6$ asteroids in total [2], among which no more than 20 objects are currently known that have very fast axial rotation periods (≤ 360 s), as well as no more than 50 objects that have slow axial rotation periods ($\geq 1.872 \cdot 10^6$ s) [3]. The orbital evolution of both asteroids was studied using a special software package EPOS [4], developed at Pulkovo Observatory.

Asteroid 2023 DZ2 ($H = 24.3^m$) was discovered on 27 February 2023 at Roque de los Muchachos Observatory (Canary Islands, Spain) [5]. At the time of its discovery, it was classified as a potentially hazardous object. Two centuries ago, the asteroid had three close approaches to Mars at a distance of less than 0.06 AU (1826, 1897 and 2020, respectively) and six with Earth at a distance of less than 0.01 AU (1810, 1855, 1923, 1991, 2004 and 2023, respectively); whereas during the last two approaches the asteroid entered the lunar orbit, so the Earth's influence on its orbit was most noticeable. In fact, the asteroid should have been discovered in 2004, but then the conditions for observations were unfavorable. Figure 1 illustrates the evolution of the asteroid's orbit as a result of the two mentioned close approaches to the Earth. In the future, the orbit, having an irregular character, will gradually „collapse" with the decrease of semi-major axis, and the object will move further into the region of the inner planets. This is the most likely scenario, except for a possible super-close approach or collision with a planet. It should be added that the asteroid goes deep into the Main Asteroid Belt and may potentially approach other massive asteroids many times, for the three of which ((24) Themis, (31) Euphrosyne, (372) Palma) this asteroid is a potentially hazardous object which was also determined from the analysis by EPOS software [4]. Figure 2 illustrates the configuration of orbits of asteroid 2023 DZ2 and the 37 largest asteroids. This possibility will further complicate the movement of this asteroid in the future and may eventually make it a potentially hazardous object again.

Based on the observation data (one observation night 23.03.2023, time interval — 18:00–21:15, 93 images were selected from 116) obtained using the ZA-320M Mirror Astrograph [6] at Pulkovo Observatory, it became possible to define the axial rotation period of asteroid 2023 DZ2 which was 376.488 ± 0.072 s that corresponds to the published results of other researches [7].

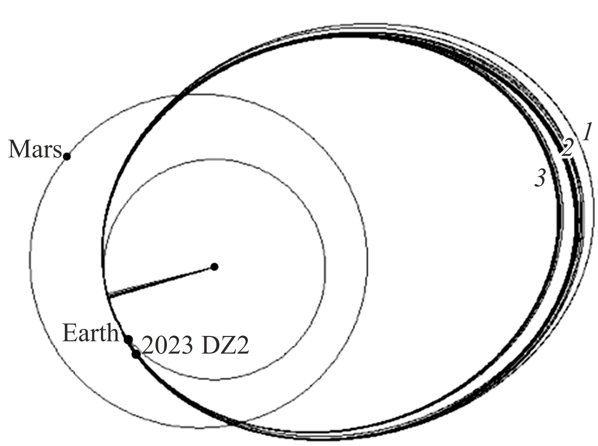


Figure 1. Orbit of asteroid 2023 DZ2: *1* — before 18 April 2004, *2* — before 25 March 2023, *3* — current state.

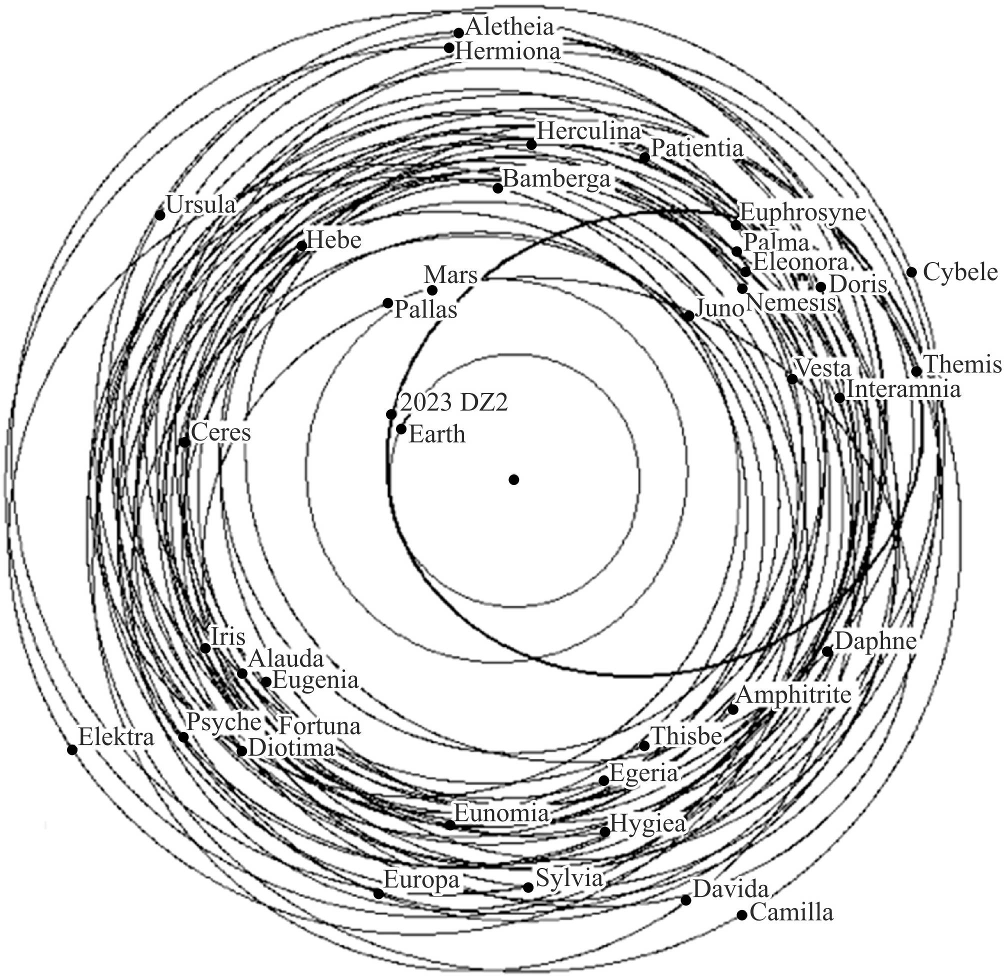
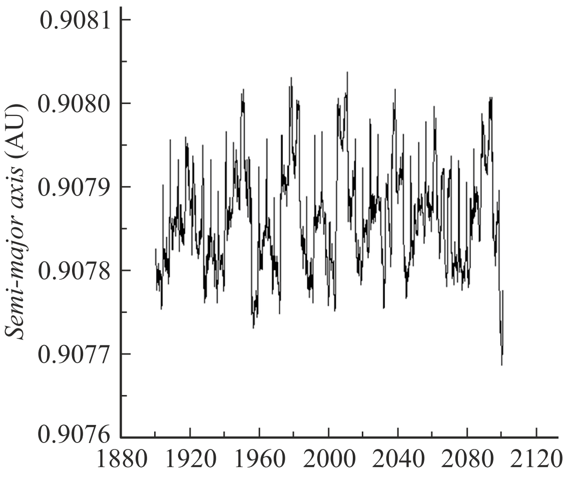


Figure 2. Orbits and positions of asteroid 2023 DZ2 and the 37 most massive asteroids at JD2460000.5 epoch.



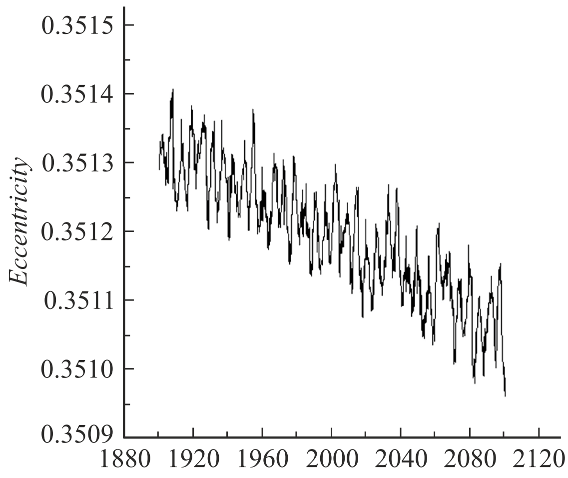


Figure 3. Evolution of semi-major axis and eccentricity of the orbit of asteroid 96590 (1998 XB) in the time interval 1900−2100.

The next close approach of asteroid 2023 DZ2 to the Earth will take place on April 4, 2026 at a distance of about 10^9 m. The maximum deviation of the asteroid under the influence of radiation pressure before this approach (in 3 years) can be $4.2 \cdot 10^4$ m. The method of analysis is described in [8], calculations for both asteroids studied

Magnitude of the Yarkovsky effect (AU) per revolution of the asteroid around the Sun as a function of the angle of inclination of its rotation axis

Asteroid	0°	45°	90°	135°	180°
2023 DZ2	$1.2872 \cdot 10^{-11}$	$0.9014 \cdot 10^{-11}$	$-0.0176 \cdot 10^{-11}$	$-0.9190 \cdot 10^{-11}$	$-1.2872 \cdot 10^{-11}$
1998 XB	$5.0766 \cdot 10^{-14}$	$3.2456 \cdot 10^{-14}$	$-0.6882 \cdot 10^{-14}$	$-3.9338 \cdot 10^{-14}$	$-5.0766 \cdot 10^{-14}$

in this paper were carried out for JD 2460200.5 epoch with initial data from the JPL Small Body Database [9,10]. The diameter D of asteroid 2023 DZ2 is estimated as 54 m [11], the density was taken as average, 3000 kg/m^3. The albedo of the asteroid δ was calculated by formula $\lg \delta = (3.122 - \lg D - 0.2H)/0.5$ [12], where H — absolute magnitude.

Asteroid 96590 (1998 XB) ($H = 16.3^m$) was discovered on December 1, 1998 at Xinglong Observatory (China). It is also a near-Earth asteroid and deserves attention because of its extremely slow rotation, one of the slowest of all known near-Earth asteroids. The asteroid's orbit does not lie close to the ecliptic plane, and it does not approach the planets closer than 0.09AU. Therefore, the asteroid's motion can be considered fairly stable for at least the next few centuries. The evolution of the orbital elements was studied over the time interval from 1900 to 2100. Figure 3 shows only a part of this study, namely, the evolution of the semi-major axis and the eccentricity of the orbit. Observations of this asteroid were also carried out at Pulkovo Observatory using the ZA-320M telescope. The next close approach of the asteroid to the Earth will take place on 4 July 2042 at a distance of about $1.3 \cdot 10^{10}$ m. By that time (in 19 years), maximal deviation of the asteroid under the impact of radiation pressure will be $1.37 \cdot 10^5$ m. This asteroid relates to the S spectral class, therefore, a density of 2710 kg/m^3 was taken for it [13].

Calculations of the Yarkovsky effect, which is a weak reactive pulse due to anisotropic thermal radiation from the surface of a rotating asteroid, were performed for both asteroids. The thermodynamic model of the Yarkovsky effect was taken from papers [14,15], and the computation method — from paper [16]. The table above shows the computational results for various possible inclination angles of the asteroid's rotation axis.

Conflict of interest

The authors declare that they have no conflict of interest.

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