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A Two-month Mini-moon: 2024 PT_5 Captured by Earth from September to November

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ABSTRACT

Near-Earth objects (NEOs) that follow horseshoe paths, and approach our planet at close range and low relative velocity, may undergo mini-moon events in which their geocentric energy becomes negative for hours, days or months, but without completing one revolution around Earth while bound. An example of NEO experiencing such a temporarily-captured flyby is 2022 NX_1, which was a short-lived mini-moon in 1981 and 2022. Here, we show that the recently discovered small body 2024 PT_5 follows a horseshoe path and it will become a mini-moon in 2024, from September 29 until November 25.

Keywords: Solar system, Asteroids

INTRODUCTION

Earth can regularly capture asteroids from the NEO population and pull them into orbit, making them mini-moons. Sometimes, these temporary captures do not complete one revolution before droping out of orbit and returning to their regular heliocentric trajectories. Following Fedorets et al. (2017), temporarily-captured flybys never complete one revolution around Earth, while temporarily-captured orbiters complete one or more. Examples of the latter were 2006 RH_{120} that remained gravitationally bound to Earth from July 2006 to July 2007 (Kwiatkowski et al. 2009) and 2020 CD_3 that escaped early in May 2020 after being bound to Earth for several years (Bolin et al. 2020; de la Fuente Marcos & de la Fuente Marcos 2020; Fedorets et al. 2020; Naidu et al. 2021). As for the temporarily-captured flybys, two examples are known: 1991 VG was briefly captured in February 1992 (Tancredi 1997; de la Fuente Marcos & de la Fuente Marcos 2018) and 2022 NX_1 was a short-lived mini-moon of Earth in 1981, 2022, and it will return as such in 2051 (de la Fuente Marcos & de la Fuente Marcos 2022; de la Fuente Marcos et al. 2023). The recently discovered Apollo-class NEO 2024 PT_5 follows a path that resembles that of 2022 NX_1 and may soon become a mini-moon.

ASTEROID 2024 PT_5: DATA

Asteroid 2024 PT_5 was discovered on 2024-August-7 by the Asteroid Terrestrial-impact Last Alert System (ATLAS, Tonry et al. 2018) observing with the instrument located in Sutherland, South Africa (Tonry et al. 2024). It has $H = 27.6 \pm 0.3$ mag and, with a size of ~ 10 m, is larger than 2020 CD_3, 2006 RH_{120}, 1991 VG, and 2022 NX_1. As of 2024-August-30, its heliocentric orbit determination (based on 122 observations spanning 21 d) is: semimajor axis, $a = 1.0123051 \pm 0.0000002$ au, eccentricity, $e = 0.02147672 \pm 0.00000005$, inclination, $i = 1.^\circ52051 \pm 0.^\circ00004$, longitude of the ascending node, $\Omega = 305.^\circ5722 \pm 0.^\circ0007$, and argument of perihelion, $\omega = 116.^\circ2485 \pm 0.^\circ0002$.[1] Such orbital elements are consistent with those of the Arjunas, a sparsely resonant population of small NEOs (see, e.g., de la Fuente Marcos & de la Fuente Marcos 2013, 2015) in a secondary asteroid belt found surrounding the path followed by the Earth–Moon system (Rabinowitz et al. 1993).

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[1] Epoch 2460600.5 (2024-Oct-17.0) TDB

ASTEROID 2024 PT_5: DYNAMICS

Figure 1 summarizes our results and provides an early assessment of the current status, and short-term past and future orbital evolution of 2024 PT_5. Our N-body calculations were carried out as detailed in de la Fuente Marcos & de la Fuente Marcos (2012), using input data from Jet Propulsion Laboratory's Small-Body Database[2] and HORIZONS[3] on-line solar system data and ephemeris computation service (Giorgini 2015), which are based on the DE440/441 planetary ephemeris (Park et al. 2021). Our computations were completed using software developed by Aarseth (2003)[4] that implements the Hermite integration scheme (Makino 1991).

Figure 1, top, shows the evolution of the relevant resonant angle or difference between the mean longitude of the NEO and that of Earth, $\lambda_{\rm r}$ (Murray & Dermott 1999), whose value is currently oscillating about 180°. Therefore, 2024 PT_5 is a transient co-orbital of the horseshoe type like 1991 VG (de la Fuente Marcos & de la Fuente Marcos 2018) or 2022 NX_1 (de la Fuente Marcos & de la Fuente Marcos 2022; de la Fuente Marcos et al. 2023). In the figure, we show the evolution of the nominal orbit and those of control orbits with state vectors (Cartesian coordinates and velocities) well away from the nominal one. Figure 1, top, also shows at the bottom the evolution of the geocentric energy, for which negative values signal capture. Figure 1, top-right, is a magnified version of the top-left panels focusing on the time interval $(-1, 1)$ yr. It shows that 2024 PT_5 will become a mini-moon of Earth on September 29, 2024 (20:02), to return to a heliocentric path 56.6 d later, on November 25 (10:33). Figure 1, bottom-left, shows the evolution of the difference between the semimajor axis of 2024 PT_5 and that of Earth, $a_{\rm r}$, as a function of $\lambda_{\rm r}$ around the epoch of the mini-moon episode. Figure 1, bottom-center and -right panels, shows the geocentric motion during $(-1, 1)$ yr. All the control orbits up to $\pm 9\sigma$ from the nominal one confirm that 2024 PT_5 is currently following a horseshoe path and that its geocentric energy will remain negative for 56.6 d due to a temporarily-captured flyby. After completing the mini-moon episode, it will approach Earth at ~ 1 km s^{-1}, reaching a minimum distance of 0.012 au on 2025-January-09, leaving the neighborhood of Earth shortly afterwards, until its next return in 2055. Differences in the evolution of the control orbits appear beyond 60 yr into the past, but also after 30 yr into the future; close encounters with the Earth–Moon system are the cause (in 1960 and 2055, respectively).

DISCUSSION AND CONCLUSIONS

The evolution of all the control orbits indicate that 2024 PT_5 will experience a temporarily-captured flyby in 2024, from September 29 until November 25. The object is unlikely to be artificial as its short-term dynamical evolution closely resembles that of 2022 NX_1, a confirmed natural object, see fig. 3 of de la Fuente Marcos et al. (2023).

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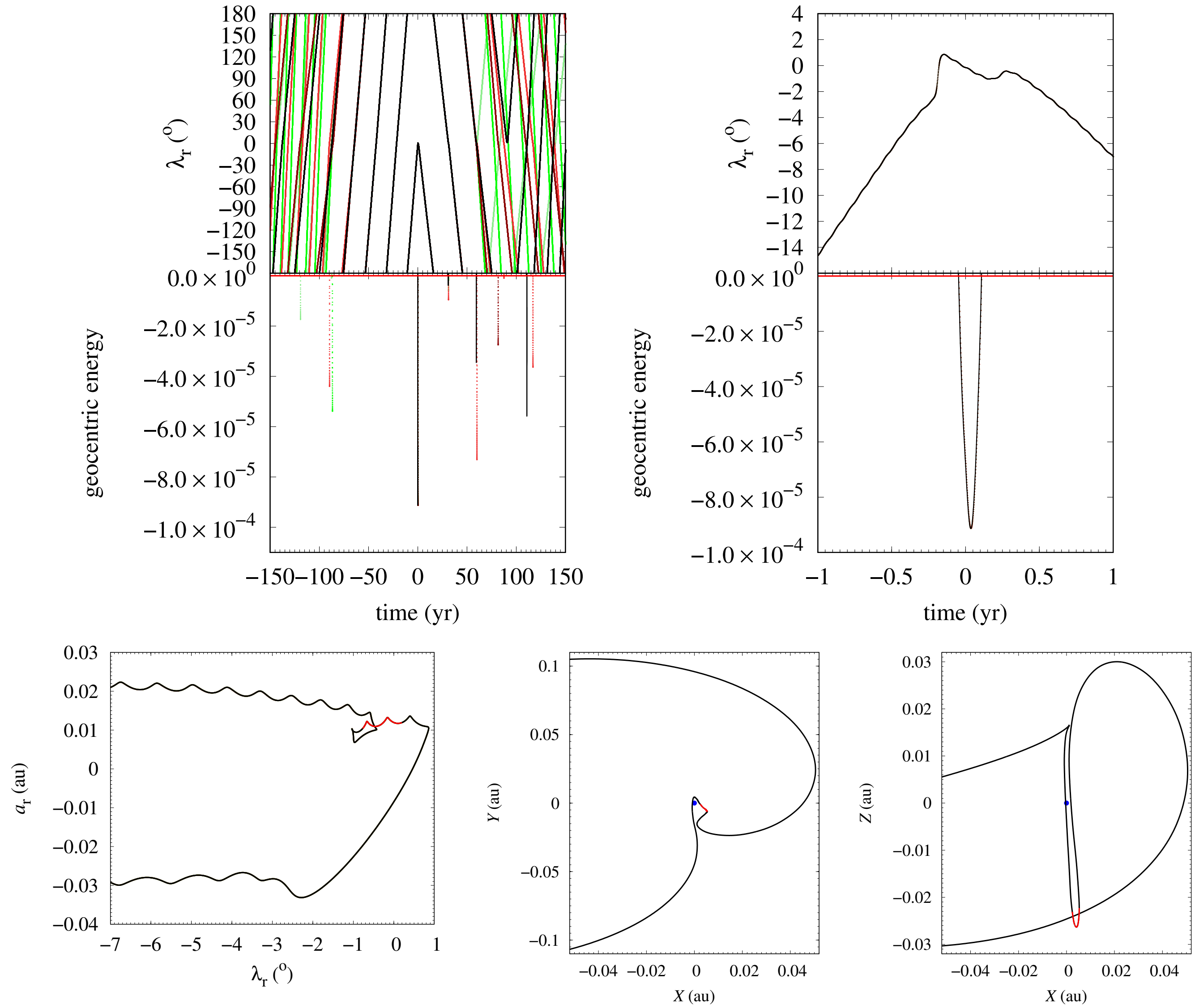

Figure 1. Evolution of the relative mean longitude of 2024 PT_5 and its geocentric energy (top), and its relative semimajor axis as a function of its relative mean longitude and its nominal geocentric motion (bottom, Earth in blue, captures in red). The top-right and bottom panels focus on the time interval $(-1,\ 1)$ yr. The bottom-left panel shows the evolution around the mini-moon episode. Top panels show the evolution of the nominal orbit (in black) and those of control orbits with state vectors separated $\pm 3\sigma$ (light-green/green) and $\pm 9\sigma$ (light-/dark-red) from the nominal one. The unit of energy is such that the unit of mass is 1 $M_{\odot}$, the unit of distance is 1 au, and the unit of time is one sidereal year divided by 2π. The output interval is 0.36525 d. The origin of time is epoch 2460600.5 (2024-Oct-17.0) TDB.

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