Asteroid 2014 YX$_{49}$: a large transient Trojan of Uranus

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ABSTRACT

In the outer Solar system, primordial Trojan asteroids may have remained dynamically stable for billions of years. Several thousands of them accompany Jupiter in its journey around the Sun and a similarly large population may be hosted by Neptune. In addition, recently captured or transient Jovian and Neptunian Trojans are not uncommon. In contrast, no Trojans of Saturn have been found yet and just one Uranian Trojan is known, 2011 QF$_{99}$. Here, we discuss the identification of a second Trojan of Uranus: 2014 YX$_{49}$. Like 2011 QF$_{99}$, 2014 YX$_{49}$ is a transient L$_d$ Trojan although it orbits at higher inclination (25.55 versus 10.83), is larger (absolute magnitude of 8.5 versus 9.7) and its libration period is slightly shorter (5.1 versus 5.9 kyr); contrary to 2011 QF$_{99}$, its discovery was not the result of a targeted survey. It is less stable than 2011 QF$_{99}$; our extensive N-body simulations show that 2014 YX$_{49}$ may have been following a tadpole trajectory ahead of Uranus for about 60 kyr and it can continue doing so for another 80 kyr. Our analysis suggests that it may remain as co-orbital for nearly 1 Myr. As in the case of 2011 QF$_{99}$, the long-term stability of 2014 YX$_{49}$ is controlled by Jupiter and Neptune, but it is currently trapped in the 7:20 mean motion resonance with Saturn. Consistently, the dynamical mechanism leading to the capture into and the ejection from the Trojan state involves ephemeral multi-body mean motion resonances.

Key words: methods: numerical – methods: statistical – celestial mechanics – minor planets, asteroids: individual: 2014 YX$_{49}$ – planets and satellites: individual: Uranus.

1 INTRODUCTION

Among the giant planets, Saturn and Uranus lack a significant present-day population of small bodies subjected to their respective 1:1 mean motion or co-orbital resonances (quasi-satellite, Trojan, horseshoe or combinations of these three elementary resonant states). This is particularly true in the case of Trojans or minor bodies librating 60° ahead (L$_d$ Lagrangian point) or behind (L$_s$) a host planet in its orbit.

Trojans describe a shifting path in the shape of a tadpole around the associated Lagrangian point when seen in a frame of reference centred at the Sun and rotating with the host planet (for further details, see e.g. Murray & Dermott 1999). Jupiter is accompanied by many thousands of them (see e.g. Milani 1993; Jewitt, Trujillo & Luu 2000; Morbidelli et al. 2005; Yoshida & Nakamura 2005; Robutel & Gobern 2006; Robutel & Bodossian 2009; Grav et al. 2011; Nesvorný, Vokrouhlický & Morbidelli 2013) and Neptune may have a similarly large population including both primordial or long-term stable Trojans (e.g. Kortenkamp, Malhotra & Michtchenko 2004; Nesvorný & Vokrouhlický 2009; Sheppard & Trujillo 2006, 2010) and transient or recently captured ones (e.g. de la Fuente Marcos & de la Fuente Marcos 2012b,c). In contrast to the cases of Jupiter and Neptune, any existing Trojans of Saturn still remain to be detected and the first Trojan of Uranus—a transient one, 2011 QF$_{99}$—was announced in 2013 (Alexandersen et al. 2013a). This long-sought first Uranian Trojan was found within the context of a carefully planned survey (Alexandersen et al. 2013b). Alexandersen et al. (2013b) have shown that 2011 QF$_{99}$ may stay as L$_d$ Trojan of Uranus for 100 kyr to 1 Myr; prior to and/or after leaving its current tadpole path, 2011 QF$_{99}$ may have experienced other co-orbital states. Unlike 2011 QF$_{99}$, Jovian or Neptunian primordial Trojans may have remained as such for the age of the Solar system or over 4.5 Gyr. In total, 2011 QF$_{99}$ may spend about 3 Myr trapped in a co-orbital resonance with Uranus. Asteroid 2011 QF$_{99}$ could be a former member of the Centaur population and it may return to it after being scattered away at the end of its current co-orbital episode.

The present-day dynamical status as Uranian Trojan of 2011 QF$_{99}$ was further confirmed by de la Fuente Marcos & de la Fuente Marcos (2014) who showed that a three-body mean motion resonance is responsible for both its insertion into Uranus’ co-orbital region and its eventual escape from there. The critical role of three-body resonances as source of instability for Uranian Trojans was first discussed by Marzari, Tricarico & Scholl (2003). Here, we identify a second Trojan of Uranus, 2014 YX$_{49}$, and explore numerically its past, current and future dynamical evolution. This paper is organized as follows. In Section 2, we show the data available on 2014 YX$_{49}$ and discuss our methodology. The orbital evolution of 2014 YX$_{49}$ is studied in Section 3, where its current dynamical
status as Uranian Trojan is confirmed statistically. In Section 4, we discuss our results within the context of our present knowledge of the population of Uranian co-orbitals. Our conclusions are summarized in Section 5.

2 Asteroid 2014 YX$_{49}$: Data and Methodology

Asteroid 2014 YX$_{49}$ was discovered on 2014 December 26 by B. Gibson, T. Goggia, N. Primak, A. Schultz and M. Willman (Gibson et al. 2016)$^3$ observing with the 1.8-m Ritchey-Chretien telescope of the Pan-STARRS Project (Kaiser et al. 2004) from Haleakala. At discovery time, its w-magnitude was 21.4, its right ascension was $7^h 29^m 22^s.659$, and its declination was $+30^\circ 24' 00''.37$ at a heliocentric distance of 18.398 au. As the primary mission of the Pan-STARRS astronomical survey is to detect incoming near-Earth objects not minor bodies moving within the outer Solar system, the discovery of 2014 YX$_{49}$ can be considered of serendipitous nature.

The discovery was made public on 2016 July 16 (Gibson et al. 2016) and during the following month a relatively large number of precovery images from other surveys were identified, which translated into a rapid improvement of its orbital determination. The solution for the orbit of 2014 YX$_{49}$ currently available (as of 2017 January 9) from Jet Propulsion Laboratory’s (JPL) Small-Body Database$^2$ is statistically robust (see Table 1) as it is based on 70 observations spanning a data-arc of 4 876 days or 13.35 yr, from 2001 September 22 to 2015 January 28. Formally classified dynamically as a Centaur, it has a value of the semimajor axis $a = 19.13$ au, and moves in an eccentric, $e = 0.28$, and rather inclined path, $i = 25.55$. It is a comparatively large object with $H = 8.5$ mag, which implies a diameter in the range 40–120 km for an assumed albedo of 0.50–0.05. Its period of revolution around the Sun, 83.7±1.3 yr at present, matches well that of Uranus and this fact makes it a strong candidate to moving co-orbital with this giant planet.

The value of the relative semimajor axis of 2014 YX$_{49}$ with respect to Uranus, $|a - a_U| = 0.00012$ au, is lower than those of any other previously documented Uranian co-orbitals — (83982) Crantor (0.304 au), 2011 QF$_{69}$ (0.079 au) and (472651) 2015 DB$_{216}$ (0.087 au) — or candidates — 1999 HD$_{12}$ (0.210 au), 2002 VG$_{131}$ (0.026 au) and 2010 EU$_{65}$ (0.265 au). Uranus’ co-orbital region goes approximately from 19.0 to 19.4 au, although co-orbitals with $a$ in the range 19.1–19.2 au are far less unstable (de la Fuente Marcos & de la Fuente Marcos 2015). The orbit of 2014 YX$_{49}$ in Table 1 indicates that it can only experience close encounters with Uranus because its perihelion distance is well beyond the aphelion of Saturn and its aphelion distance is far shorter than the perihelion of Neptune; this property suggests that 2014 YX$_{49}$ may be as dynamically stable as 2011 QF$_{69}$ or 472651.

The path currently followed by 2014 YX$_{49}$ is more eccentric than that of 2011 QF$_{69}$ (0.277 versus 0.178) and also more inclined (25.55 versus 10.83). Although the values of their respective arguments of perihelion are separated by just 7.5, their longitudes of the ascending node are over 131 $^\circ$ apart. As for a comparison between the orbits of 2014 YX$_{49}$ and 472651, the former moves in a less eccentric (0.277 versus 0.326) and also less inclined (25.55 versus 37.70) path. In terms of its present-day orbit, the dynamical behaviour of 2014 YX$_{49}$ could be intermediate between those of 2011 QF$_{69}$ and 472651.

The actual dynamical status of prospective co-orbital bodies is not assessed directly from their present-day orbits but from the analysis of a relevant set of numerical integrations. Such analysis focuses on the study of the behaviour of a critical angle that, in the case of Uranus’ co-orbital candidates, is the relative mean longitude $\lambda = \lambda - \lambda_U$, where $\lambda$ and $\lambda_U$ are the mean longitudes of the object and Uranus, respectively; $\lambda = M + \Omega + \omega$, where $M$ is the mean anomaly, $\Omega$ is the longitude of the ascending node, and $\omega$ is the argument of perihelion (see e.g. Murray & Dermott 1999).

For non-co-orbital or passing bodies $\lambda_U \in (0, 360)^\circ$, with all the values being equally probable; this behaviour is known as circulation. True co-orbitals exhibit an oscillatory evolution over time of the value of $\lambda_U$; this behaviour is known as libration. For a L$_4$ Trojan the libration is around $+60^\circ$, for a L$_5$ Trojan the libration is around $-60^\circ$ or $300^\circ$ (see e.g. Murray & Dermott 1999), although the oscillation centre could be significantly shifted from the typical equilateral location in the case of eccentric orbits (Namouni, Christou & Murray 1999; Namouni & Murray 2000). The current value of $\lambda_U$ for 2014 YX$_{49}$ is $-61^\circ$, which suggests that 2014 YX$_{49}$ could be indeed a present-day Uranian Trojan, but this must be confirmed using N-body simulations (for 2011 QF$_{69}$, a Trojan, is $-47^\circ$ and $-170^\circ$ for 472651, a horseshoe librator).

As in our previous studies on the dynamics of Crantor (de la Fuente Marcos & de la Fuente Marcos 2013), 2011 QF$_{69}$ (de la Fuente Marcos & de la Fuente Marcos 2014) and 472651 (de la Fuente Marcos & de la Fuente Marcos 2015), we use direct N-body integrations performed with a modified version of a code written by Aarseth (2003) — the standard version of this software is publicly available from the IoA website$^1$ — that implements the Hermite integration scheme described by Makino (1991). The performance of this code, when applied to Solar system numerical investigations, has been studied thoroughly (for further details, see de la Fuente Marcos & de la Fuente Marcos 2012a). The physical model is the same one used in the works on Crantor, 2011 QF$_{69}$ and 472651 cited above and includes the perturbations by the eight major planets, the Moon, the barycentre of the Pluto-Charon system, and the three largest asteroids. Initial positions and velocities are based on the DE405 planetary orbital ephemerides (Standish 1998) referred to the barycentre of the Solar system and to the epoch JD TDB

1. http://www.minorplanetcenter.net/iau/mpcc/K16/K16O10.html

2. http://ssd.jpl.nasa.gov/sdb/cgi

3. http://www.ast.cam.ac.uk/~sverre/web/pages/nbody.htm
3 ASTEROID 2014 YX₄⁹: ORBITAL EVOLUTION

In this section, we show the results of simulations that use the nominal orbit in Table 1 and those of additional control calculations based on sets of orbital elements obtained from the nominal ones as described in de la Fuente Marcos & de la Fuente Marcos (2013, 2014, 2015). The main set of numerical integrations explores the dynamical evolution of 2014 YX₄⁹ for 0.6 Myr forward and backwards in time. Another set of shorter simulations aimed at characterizing the short-term stability of 2014 YX₄⁹ applies the implementation of the Monte Carlo using the Covariance Matrix (MCCM) method discussed by de la Fuente Marcos & de la Fuente Marcos (2015).

3.1 Current dynamical state

Fig. 1, left-hand panel, displays the motion of 2014 YX₄⁹ as characterized by the nominal orbit shown in Table 1 over the time range (−3 286, 1 840) yr projected on to the ecliptic plane in a coordinate system centred at the Sun and rotating with Uranus. This figure is equivalent to fig. 1 for 2011 QF₉₉ in Alexandersen et al. (2013b) or fig. 1 in de la Fuente Marcos & de la Fuente Marcos (2014). Only one oscillation of the tadpole motion of 2014 YX₄⁹ is displayed (see the evolution of λ, Fig. 1, right-hand panel). All the control orbits (several hundreds) show virtually the same behaviour in the neighbourhood of \( t = 0 \). Alexandersen et al. (2013b) have found a libration period for 2011 QF₉₉ of 5.9 kyr. Our calculations indicate that the libration period of 2014 YX₄⁹ is slightly shorter, of about 5.1 kyr. Fig. 1 confirms 2014 YX₄⁹ as the second Trojan of Uranus; this conclusion is robust because the results of the evolution of a large set of statistically consistent short integrations (lasting \( \pm 20 \) kyr) are virtually identical to each other.

Fig. 2 shows the variation of the orbital elements \( a, e, i, \Omega, \) and \( \omega \) of 2014 YX₄⁹ over time. This figure displays the average evolution (black curve) of 250 control orbits obtained via MCCM and its associated dispersion (red curves). These control orbits have been computed as described in section 3 of de la Fuente Marcos & de la Fuente Marcos (2015). The covariance matrix used to perform these calculations was provided by JPL’s Small-Body Database. The overall level of stability that characterizes the orbital solution currently available for 2014 YX₄⁹ can be evaluated quantitatively by computing its associated Lyapunov time or time-scale for exponential divergence of orbits that are started arbitrarily close to each other. Our calculations show that the Lyapunov time is somewhat different for forward (\( \sim 20000 \) yr) and backwards (\( \sim 9000 \) yr) integrations; this is relatively common in the case of transient co-orbital. For instance, the Lyapunov time of 2011 QF₉₉ is longer for backwards integrations. In the short term, 2014 YX₄⁹ is clearly more stable than (472651) 2015 DB₁₁₁ (see fig. 1 in de la Fuente Marcos & de la Fuente Marcos 2015); asteroid 472651 is a Uranian asymmetric horseshoe librator.

\[ \text{Figure 1. One oscillation of the Trojan motion of 2014 YX₄⁹ during the time interval (−3 286, 1 840) yr projected on to the ecliptic plane in a coordinate system centred at the Sun and rotating with Uranus (left-hand panel). The path followed by Uranus and its position are plotted as well; in this frame of reference, and as a result of the non-negligible value of its orbital eccentricity, Uranus follows a small ellipse. The values of the resonant angle, } \lambda, \text{ for one libration period are also shown (right-hand panel). Nominal orbital solution as in Table 1 although the behaviour observed is virtually identical across control orbits within the displayed time frame.} \]

\[ \text{Figure 2. Variation of the orbital elements } a \text{ (top panel), } e \text{ (second to top panel), } i \text{ (middle panel), } \Omega \text{ (second to bottom panel), and } \omega \text{ (bottom panel) of 2014 YX₄⁹ over time (a,20000 yr). The average evolution of 250 control orbits is shown as a thick black curve; the corresponding ranges in the values of the orbital parameters are displayed as thin red curves. The control orbits utilized to generate the initial conditions for this set of simulations have been calculated as described in section 3 of de la Fuente Marcos & de la Fuente Marcos (2015), using the covariance matrix.} \]
3.2 Past and future orbital evolution

Fig. 3, central panels, shows the time evolution of various parameters for the nominal orbit of 2014 YX₄₀ in Table 1 over an interval of ±0.6 Myr. In addition to the nominal orbit, results for two other representative control orbits are also displayed (left-hand and right-hand panels); they have been computed by adding (+) or subtracting (−) 6-times the uncertainty from the orbital elements (the six parameters) in Table 1. The comparative evolution shows that 2014 YX₄₀ is a transient L₃ Trojan of Uranus. We have already pointed out above that close encounters of 2014 YX₄₀ with Saturn or Neptune are not possible; Fig. 3, A-panels, indicate that no close approaches to Uranus under one Hill radius are recorded during the studied time interval. Fig. 3, B-panels, shows that the duration of the present Trojan episode of 2014 YX₄₀ is expected to be shorter than that of 2011 QF₉₀ (see fig. 4 in de la Fuente Marcos & de la Fuente Marcos 2014). In general, the dynamical evolution of 2014 YX₄₀ is more complex than that of 2011 QF₉₀ and multiple transitions between the various incarnations of the 1:1 mean motion resonance with Uranus are observed. Our calculations show that 2014 YX₄₀ may become a transient L₃ Trojan but also engage in quasi-satellite (the value of \( \lambda \) oscillates around 0°) or horseshoe behaviour (\( \lambda \) librates around the Lagrangian point L₃, which is located at 180° from Uranus on its orbit); trajectories hybrid of two (or more) elementary co-orbital states are also possible (see Fig. 3, B-panels). During most of the Trojan phase, the amplitude of the oscillation of the tadpole motion is < 70°.

The evolution of the value of the semimajor axis (Fig. 3, C-panels) provides insight on how much time 2014 YX₄₀ spends within Uranus’ co-orbital zone. Our calculations indicate that this minor body may be co-orbital to Uranus for an average of 600 kyr with a minimum of about 400 kyr and a maximum close to 1 Myr. This makes it less long-term stable than both 2011 QF₉₀ and 472651. In general, the values of \( e \) (Fig. 3, D-panels) and \( \iota \) (Fig. 3, E-panels) do not exhibit obvious signs of coupling as those characteristic of the Kozai resonance (Kozai 1962); this is consistent with the behaviour of the argument of perihelion (Fig. 3, F-panels) that mostly circulates. When compared with 2011 QF₉₀, 2014 YX₄₀ shows significantly less evidence of Kozai-like resonant behaviour.

Fig. 3, G-panels, shows the evolution of the distance to the nodes of 2014 YX₄₀ over time; the separation between the Sun and the nodes has been computed by applying the expression \( r = a(1 - e^2)/(1 + e \cos \omega) \), where the ‘+’ sign is used for the ascending node and the ‘−’ sign for the descending node. In the case of Solar system objects that move in orbits inclined with respect to the ecliptic plane, close encounters with major planets can only take place in the vicinity of the nodes. Our calculations show that the evolution is quite regular and resembles that of 2011 QF₉₀ (see fig. 4, G-panels, in de la Fuente Marcos & de la Fuente Marcos 2014).

The secular dynamics of known Uranian co-orbitals has been studied in de la Fuente Marcos & de la Fuente Marcos (2014) and de la Fuente Marcos & de la Fuente Marcos (2015). These studies singled out 472651 as peculiar because the precession frequency of the longitude of the perihelion, \( \sigma = \Omega + \omega \), of this object is not in secular resonance with Jupiter, Saturn or Uranus, only with Neptune and for a limited amount of time. Fig. 4 shows the time evolution of the relative longitude of the perihelion, \( \Delta \sigma \), of 2014 YX₄₀ with respect to the giant planets. The precession frequency of the longitude of the perihelion of 2014 YX₄₀ is only in secular resonance with Neptune, but for the entire simulation. The value of \( \Delta \sigma = \sigma - \sigma_N \) librates around -90° (or 270°). This type of secular behaviour is not observed for any other known Uranian co-orbital. The time evolution of the relative longitude of the perihelion with respect to Jupiter, Saturn and Uranus closely resembles that of 472651 (see fig. 5 in de la Fuente Marcos & de la Fuente Marcos 2015).
Figure 3. Past and future evolution of various relevant parameters for the nominal or reference orbit of 2014 YX₄⁹ in Table 1 (central panels) and two illustrative orbits that are most different from the reference one (see the text for details). The variation of the distance from Uranus over time (A-panels) also plots the value of the Hill sphere radius of Uranus (0.4469 au) as a red line. The time evolution of the value of the resonant angle, $\lambda_r$ (B-panels), shows that this Trojan is transient. The variation of its semimajor axis, $a$ (C-panels) suggests that this object may remain as Uranian co-orbital for close to 1 Myr; the value of the semimajor axis of Uranus appears as a red line. The evolution of both eccentricity, $e$ (D-panels), and inclination, $i$ (E-panels), is far from regular. The argument of perihelion, $\omega$ (F-panels), mostly circulates. The values of the distance to the nodes from the Sun (G-panels) oscillate somewhat regularly; the distance from the Sun to the descending (ascending) node is shown as a thick (dotted) line with Uranus’ semimajor axis, and the distances to Saturn’s aphelion and Neptune’s perihelion, plotted as red lines.
Additional examples of similar transitions for the cases of 2011 QF$_{99}$ and 472651 can be found in de la Fuente Marcos (2014) and de la Fuente Marcos & de la Fuente Marcos (2015), respectively. As pointed out in de la Fuente Marcos & de la Fuente Marcos (2015), the outcome of these rapid transitions is unusually sensitive to the physical model used to perform the calculations. A five-body physical model including the Sun and the four outer planets such as the one used by Marzari et al. (2003) or Alexandersen et al. (2013b) may not be able to arrive to realistic conclusions regarding the resonant details associated with the transitions between co-orbital states experienced by objects like 2011 QF$_{99}$, 2014 YX$_{49}$ and 472651.

4 DISCUSSION

The discovery of 2014 YX$_{49}$, the second Uranian Trojan, confirms that, contrary to the conclusions reached by Horner & Evans (2006), Uranus can capture efficiently minor bodies into the 1:1 mean motion resonances. In addition, the fact that it was originally found at a declination above $+30^\circ$ by Pan-STARRS strongly suggests that the number of objects moving in similar orbits may not be negligible (see the detailed discussion in section 8 of de la Fuente Marcos & de la Fuente Marcos 2014). Asteroid (472651) 2015 DB$_{216}$ is another example of transient Uranian co-orbital discovered under similar circumstances, i.e. serendipitously. If the analysis in de la Fuente Marcos & de la Fuente Marcos (2015) showed that there is enough theoretical ground to assume that a population of high orbital inclination Uranian co- orbitals may exist, the identification of this Trojan shows that there are also robust observational grounds, adding more weight to the hypothesis. Both 2014 YX$_{49}$ and 472651 are comparatively large and bright, making them easier to detect; finding any fainter, hypothetical bodies moving in somewhat similar orbits may require a carefully planned survey though.

Dvorak, Bazsó & Zhou (2010) investigated the stability of putative primordial Uranus’ Trojans and found stable islands at the inclination intervals $(0, 7^\circ)$, $(9, 13^\circ)$, $(31, 36^\circ)$ and $(38, 50^\circ)$. Asteroid 2011 QF$_{99}$, the first Uranian Trojan, inhabits one of these stable areas as its current value of the orbital inclination is nearly $11^\circ$; however, this object is not a primordial Uranus’ Trojan (Alexandersen et al. 2013b; de la Fuente Marcos & de la Fuente Marcos 2014). In contrast, 2014 YX$_{49}$ currently occupies (see Fig. 3, E-panels) an unstable region between two of the stable islands described in Dvorak et al. (2010) as its current value of the inclination is nearly $26^\circ$. In addition, its inclination remains in the range $20^\circ$–$27^\circ$ for most of the studied time. However, our analysis shows that even if 2014 YX$_{49}$ is less dynamically stable than 2011 QF$_{99}$, it can still remain as transient Trojan of Uranus for a relatively long period of time. The situation is similar to that of 472651, although this object moves in a higher inclination orbit.

Our results provide additional confirmation that overlapping mean motion resonances can trigger transitions between co-orbital states and also deliver minor bodies inside the co-orbital zone of a planetary body as well as evict them from there. The duration of these episodes is short, typically 10–20 kyr in the cases of captures as co-orbitals or ejections from the co-orbital zone, and about 5 kyr when inducing transitions between the various co-orbital states (see Figs 6 and 7). The dynamical effects of three-body mean motion resonances have been studied recently by Gallardo (2014).
Figure 6. Two examples of capture into the 1:1 mean motion resonance with Uranus for two different control orbits of 2014 YX₄₉ (left-hand and central panels) and one example of ejection (right-hand panels). Resonant arguments as in Fig. 5.

Figure 7. Two examples of transitions of 2014 YX₄₉ within the 1:1 mean motion resonance with Uranus induced by very brief resonant episodes with Jupiter. During these ephemeral events, a three-body resonance with Jupiter and Uranus is active. Resonant arguments as in Fig. 5.

5 CONCLUSIONS

In this paper, we provide a detailed exploration of the past, present and future orbital evolution of 2014 YX₄₉, the second Trojan of Uranus. Our conclusions can be summarized as follows.

(i) Asteroid 2014 YX₄₉ is a transient L₄ Trojan of Uranus, the second minor body to be confirmed as currently engaged in this type of resonant state. Its current libration period is over 5 100 yr.

(ii) Although 2014 YX₄₉ may have remained in its current Trojan state for about 60 kyr, it can continue doing so for another 80 kyr. Our calculations suggest that it may stay within Uranus’ co-orbital zone for nearly 1 Myr.

(iii) In addition to being a Uranian Trojan, 2014 YX₄₉ is currently trapped in the 7:20 mean motion resonance with Saturn; therefore, this minor body is currently subjected to a three-body resonance. It is also engaged in a long-term secular resonance with Neptune.

(iv) The dynamical mechanism behind the insertion of 2014 YX₄₉ in Uranus’ co-orbital zone involves a brief episode
of concurrent resonant behaviour with Jupiter (1:7) and Neptune (2:1). A virtually identical mechanism is also responsible for scattering 2014 YX₄⁹ away from the 1:1 commensurability with Uranus.

(v) Transitions between the various states within the 1:1 mean motion resonance with Uranus are mainly triggered by ephemeral resonant episodes with Jupiter.

(vi) Our analysis shows that 2014 YX₄⁹ shares a number of dynamical characteristics with (472651) 2015 DB₂₁₆, another Uranian co-orbital that follows a relatively high-inclination orbit. As these two objects are comparatively rather bright/large, the presence of fainter/smaller minor bodies following somewhat similar paths is highly probable and this plausible conjecture lends credibility to the idea that a population of temporary Uranian co-orbitals may exist at relatively high orbital inclinations.

Our investigation of the dynamics of 2011 QF₉₉, 472651 and 2014 YX₄⁹ shows that ephemeral multibody mean motion resonance episodes are behind the events that lead to the capture and ejection of transient Uranian co-orbitals. This general mechanism may have also played some role in the loss of any putative primordial Uranus’ Trojans early in the history of the Solar system.

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