# Orbital evolution of dormant short-period near-Earth comet candidates

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**Abstract.**
We computed the dynamical orbital evolution of 23 dormant short-period near-Earth comet candidates (NECs) during 1 Gy forward and backward integrations.

We show that most of the NECs that impact the Sun have starting orbital element eccentricities and inclinations with greater values. In contrast, objects that mainly escape our Solar System have smaller starting eccentricities and inclinations.

Moreover, we observed that the majority of objects are controlled by the aphelion of Mars or Earth and by the perihelion of Jupiter. It is interesting that the presented NECs lie around a 2:1 mean motion resonance (MMR) with Jupiter, and are bounded by a 3:1 MMR with Jupiter.

We also studied the orbital evolution of these objects without and with the Yarkovsky effect. It appeared that the average dynamical half-time is about 1.5 My for the near-Earth comets and is almost the same during forward and backward integrations. Moreover, the orbital evolution of NECs almost does not depend on the Yarkovsky effect. The mean maximum dynamical lifetime of clones of these objects is about 70 My for all studied cases.

**Key words:** Comets: general – Minor planets, asteroids: general

## Introduction

From the population of NEAs on comet-like orbits, Mommert et al. (2015) selected 23 asteroids with geometric albedos of $p_v$ <0.064 as dormant comet candidates (NECs). They used the limitation of the albedo of comet nuclei similar to that in Fernández et al. (2005). Using the WISE data, Licandro et al. (2016) found the mean geometric albedo value of 49 asteroids in Jupiter family cometary orbits and 16 in Halley-type cometary orbits, which were $0.05 \pm 0.01$, and $0.05 \pm 0.02$, respectively. These values are similar to those of the albedo of the Jupiter family comets with a $p_v$ <0.04, and to those in Mommert et al. (2015) for dormant comet candidates.

Studying the orbital evolution of the NEAs, and particularly of dormant comet candidates, is important to understanding the time evolution of the Solar System. To study this we should take into account the physical parameters of these objects and use them in a suitable integration. We used the physical parameters of the NECs given by Mommert et al. (2015) and the Swift software made by Broz (2003).

## 1. Swift integration of the orbital elements of the near-Earth comets

To compute the time evolution of the orbits of the selected near-Earth comet candidates (NECs) we used their physical parameters as presented in Table 2 of Mommert et al. (2015). Their Table 2 contains 23 physical parameters of dormant short-period near-Earth comet candidates - six of them have double physical parameters. Hence, we have 29 different starting data of the NECs. Moreover, Table 2 contains NEAs with orbits and albedos that resemble those of short-period NECs, i.e., $2.0 < T_J < 3.0$ and $Q \geq 4.5$ AU or $MOID_J$ and $p_V < 0.064$. For each object, they listed its diameter d, geometric albedo $p_V$, Tisserand parameter with Jupiter $T_J$, minimum orbit intersection distance for Jupiter $MOID_J$, perihelion distance $Q$ and absolute magnitude $H$.

First, we computed for the epoch 2015 June 27 (JD2457200.5) the starting orbital elements of all the selected NECs using observations taken from the International Astronomical Union Minor Planet Center (http://131.142.195.59/db_search). We used the OrbFit software package (http://adams.dm.unipi.it/∼orbmaint/orbfit/) and the JPL DE406 planetary and lunar ephemerides biased error model based on Chesley et al. (2010), with 25 additional perturbing asteroids, and followed the same method in the weighting and selection of observations used by the NEODyS site (Farnocchia et. al (2013)). For each NEC, we computed for the epoch 2015 June 27 (JD2457200.5) 101 virtual orbits (clones), $3\sigma$ uncertainty and the multiple solution method of Milani et al. (2005a, b).

The precision of the orbital computations using the OrbFit software is described in Wlodarczyk (2009). The orbital elements of the selected asteroids are computed without any non-gravitational effects, i.e., in our computation we used a pure gravitational model of the Solar System.

Then the starting orbital elements of the NECs and planets for the same epoch were computed with the software Mercury (Chambers (1999)). We used software Mercury because it allows us to compute necessary position of planets. Next, we added these starting orbital elements as input files to the Swift software, mainly *swift_rmvs3_f* and *swift_rmvs3_f_y* (Broz, 2003) which allowed us to compute the time evolution of the orbital elements of NECs without and with the Yarkovsky effects, respectively. Integration was performed 1 Gy forward and 1 Gy backward, without and with the Yarkovsky effects. In both cases we start integrations at 2015 June 27 (JD2457200.5). We have used a variable time step in both integrations. The results, i.e., the orbital elements of the NECs, were outputted for every 1 My.

### 1.1. Dynamical lifetimes

Table 1 lists the dynamical lifetimes of the dormant short-period near-Earth comet candidates (NECs) during forward and backward integration, without and with the Yarkovsky effects. Half-time denotes the time after 50% of the clones of a given NEC are excluded from integration. Max. denotes the maximum time of the last surviving clone of the given NEC in our integration.

As shown in Table 1, on average, half of the clones of the NECs escape from integration in about 1.2 My in the forward integration without the Yarkovsky effect and in about 1.4 My with the Yarkovsky effect. Similar values, 1.5 My and 1.6 My, were detected in the backward integration.

On the other hand, the maximum lifetime of the last surviving clone is about 61.7 My to 75.1 My for all studied cases - see Table 1. It means that only one of all 101 clones of each NEC can survive until this time, in mean. It is worth noting that half-time is only of about 1.5 My mainly because of chaotic motion of the NEC caused by approaches with planets - see Table 2.

**Table 1.** Dynamical lifetimes of dormant short-period near-Earth comet candidates during forward and backward integration, without and with the Yarkovsky effects.

| No. | NEC | Half-time (My) | Max. (My) | Half-time (My) | Max. (My) |
|---|---|---|---|---|---|
| | | Without Y. | | With Y. | |
| | | F/B | F/B | F/B | F/B |
| 1 | 3552 Don Quichote | 0.2/0.3 | 4/13 | 0.3/0.3 | 8/15 |
| 2 | 5370 Taranis | 0.6/1.0 | 51/110 | 0.5/1.2 | 61/13 |
| 3 | | | | 0.5/1.0 | 185/55 |
| 4 | 2086 | 1.1/1.1 | 20/37 | 1.1/1.2 | 33/39 |
| 5 | 248590 | 0.1/0.5 | 379/65 | 0.1/0.5 | 63/35 |
| 6 | 385402 | 1.0/6.8 | 100/118 | 8.3/6.9 | 125/114 |
| 7 | | | | 6.3/8.4 | 75/108 |
| 8 | 2000 HD74 | 8.2/7.0 | 158/136 | 8.3/7.8 | 263/68 |
| 9 | | | | 5./7.1 | 120/101 |
| 10 | 2001 HA4 | 1.0/1.7 | 69/84 | 1.4/1.8 | 32/71 |
| 11 | 2004 EB | 1.2/1.2 | 18/103 | 1.5/1.0 | 15/18 |
| 12 | 2004 YR32 | 0.6/1.2 | 147/24 | 0.6/1.2 | 57/45 |
| 13 | 2004 YZ23 | 5.8/5.9 | 100/271 | 5.4/6.3 | 127/144 |
| 14 | 2009 KC3 | 0.3/0.6 | 13/9 | 0.3/0.7 | 61/21 |
| 15 | 2009 WF104 | 1.0/1.3 | 34/31 | 1.1/1.0 | 66/233 |
| 16 | 2009 WO6 | 0.7/0.6 | 42/90 | 0.8/0.7 | 110/12 |
| 17 | 2009 XE11 | 0.7/0.6 | 76/60 | 0.6/0.7 | 46/77 |
| 18 | 2010 AG79 | 1.3/0.8 | 56/32 | 1.2/0.6 | 24/44 |
| 19 | 2010 DH77 | 0.6/0.9 | 18/67 | 0.6/0.8 | 37/60 |
| 20 | | | | 0.6/0.8 | 46/58 |
| 21 | 2010 FJ81 | 0.2/0.2 | 15/7 | 0.3/0.3 | 383/8 |
| 22 | | | | 0.2/0.2 | 79/3 |
| 23 | 2010 FZ80 | 0.3/0.4 | 31/68 | 0.3/0.4 | 3/17 |
| 24 | 2010 JL33 | 0.3/0.4 | 88/45 | 0.4/0.5 | 223/174 |
| 25 | 2010 LR68 | 0.4/0.3 | 36/11 | 0.3/0.3 | 104/70 |
| 26 | 2010 LV108 | 0.2/0.3 | 56/46 | 0.3/0.3 | 28/25 |
| 27 | 2010 GX62 | 0.8/1.0 | 17/44 | 0.7/0.9 | 42/67 |
| 28 | | | | 0.7/0.9 | 27/35 |
| 29 | 2011 BX18 | 0.8/0.9 | 8/32 | 0.5/0.7 | 6/34 |
| | Mean | 1.2/1.5 | 64.3/65.3 | 1.4/1.6 | 75.1/61.7 |

## 1.2. Interesting dynamical events

From the output file in the Swift software, we can get information about some interesting dynamical events during integration, such as:
Particle xxx too far from Sun at time...
Particle xxx perihelion distance too small at time...
Particle xxx q with respect to Planet yyy is too small at time...
Particle xxx too close to Planet yyy at time...
where xxx denotes serial number of clone, and yyy denotes the serial number of the perturbing planet from Mercury to Neptune.

Table 2 counts these events during forward integration of the NECs. The columns denote the following:
$too\,far$ — the clone is too far from the Sun, i.e., it reached the ejection

distance (1000 au)
*perihelion* — the clone impacts the Sun
*Mercury to Neptune* — the perihelion distance of particle q, with respect to given planet is smaller than 0.005 AU (radius of the Sun)
sign "+" in these columns denotes a clone that is closer to a given planet than its radius of the Roche sphere
W and Y denote the results of computations without and with the Yarkovsky effect.

It is noted that the first two cases-when the clone is too far from the Sun and its perihelion distance is too small - do not depend on using the Yarkovsky effect. On the other hand, a number of particularly close approaches with planets or with their orbits do depend on the Yarkovsky effect. Moreover, we observed many interesting events among the Earth-type planets, including impact cases. We observed some close approaches of clones with orbits of Jupiter and Saturn. However, we did not observe any close approaches with these two planets. In the case of Uranus and Neptune, we did not observe any close approaches. It is interesting in Table 2 that on average, clones mainly have close approaches with Mars - about 5% of all clones.

**Table 2.** Dynamical events during forward orbital time evolution of dormant short-period near-Earth comet candidates. Added values (+) in columns with planets denote clones that are too close to this planet, which is closer than the radius of the Roche sphere of the given planet.

| No. | NEC | too far W/Y | perihelion W/Y | Mercury W/Y | Venus W/Y | Earth W/Y | Mars W/Y | Jupiter W/Y | Saturn W/Y | Uranus W/Y | Neptune W/Y |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3552 Don Quichote | 77/79 | 16/15 | 0 | 0 | 0 | 8/5 | 0/2 | 0 | 0 | 0 |
| 2 | 5370 Taranis | 70/71 | 26/21 | 1/0 | 0/3 | 0 | 4/4 | 0/2 | 0 | 0 | 0 |
| 3 | | -/78 | -/19 | -/0 | -/0 | -/1 | -/2 | 0 | 0 | 0 | 0 |
| 4 | 2086 | 58/48 | 39/46 | 0/1 | 2/0 | 0/0 | 2/6 | 0 | 0 | 0 | 0 |
| 5 | 248590 | 29/28 | 67/68 | 0 | 0 | 0 | 4/5 | 1/0 | 0 | 0 | 0 |
| 6 | 385402 | 12/10 | 68/69 | 7+4/9+4 | 1+1/2+4 | 2/0 | 1/1 | 0 | 0 | 0 | 0 |
| 7 | | -/5 | -/75 | -/3+3 | -/6 | -/1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 2000 HD74 | 13/15 | 70/75 | 2+5/1+2 | 2+4/3+2 | 2/0 | 0/ | 1/0 | 0 | 0 | 0 |
| 9 | | -/18 | -/76 | -/1 | -/0 | -/2 | -/3 | 0 | 0 | 0 | 0 |
| 10 | 2001 HA4 | 20/28 | 73/55 | 0+1/1+2 | 1+3/3 | 0/2 | 2/7 | 0/1 | 0 | 0 | 0 |
| 11 | 2004 EB | 42/52 | 52/45 | 0 | 2/0 | 1/0 | 4/4 | 0 | 0 | 0 | 0 |
| 12 | 2004 YR32 | 22/31 | 74/64 | 0 | 0/1 | 0 | 3/4 | 0/1 | 0 | 0 | 0 |
| 13 | 2004 YZ23 | 22/17 | 63/69 | 1+5/1+3 | 4+2/2+2 | 1/0 | 1/1 | 0/1 | 0 | 0 | 0 |
| 14 | 2009 KC3 | 85/86 | 11/9 | 0/1 | 0/1 | 0 | 2/2 | 2/2 | 1/0 | 0 | 0 |
| 15 | 2009 WF104 | 63/70 | 31/27 | 0 | 1/1 | 0 | 5/3 | 1/ | 0 | 0 | 0 |
| 16 | 2009 WO6 | 68/67 | 28/26 | 1/0 | 0/1 | 0 | 4/6 | 0/1 | 0 | 0 | 0 |
| 17 | 2009 XE11 | 66/75 | 27/22 | 0+2/0 | 0/1 | 0/0 | 5/1 | 1/0 | 0 | 0 | 0 |
| 18 | 2010 AG79 | 63/54 | 33/35 | 0+1/0 | 0 | 0/2 | 4/7 | 0/2 | 0 | 0 | 0 |
| 19 | 2010 DH77 | 69/60 | 25/35 | 0/1 | 0 | 0/+1 | 6/2 | 0 | 0 | 0 | 0 |
| 20 | | -/64 | -/30 | 0 | 0 | 0 | -/5 | -/1 | 0 | 0 | 0 |
| 21 | 2010 FJ81 | 78/79 | 16/17 | 0 | 0 | 0 | 7/4 | 0/1 | 0 | 0 | 0 |
| 22 | | -/74 | -/18 | 0 | 0 | 0 | -9 | 0 | 0 | 0 | 0 |
| 23 | 2010 FZ80 | 62/64 | 32/34 | 0 | 0 | 0 | 7/2 | 0/1 | 0 | 0 | 0 |
| 24 | 2010 JL33 | 71/68 | 21/24 | 0/1+2 | 2/0 | 0 | 5/2 | 1/3 | 1/1 | 0 | 0 |
| 25 | 2010 LR68 | 92/91 | 4/3 | 0 | 1/0 | 0 | 2+1/4 | 0/2 | 2/1 | 0 | 0 |
| 26 | 2010 LV108 | 79/86 | 9/5 | 0+1/1+2 | 1+1/0+1 | 0 | 5/3 | 3/2 | 1/0 | 0 | 0 |
| 27 | 2010 GX62 | 51/49 | 46/46 | 0 | 0/2 | 0 | 3/2 | 0/1 | 1/1 | 0 | 0 |
| 28 | | -/46 | -/50 | -/0+1 | 0 | 0 | -3/ | -/1 | 0 | 0 | 0 |
| 29 | 2011 BX18 | 41/47 | 55/44 | 1/0 | 0 | 0/1 | 4/8 | 0/1 | 0 | 0 | 0 |

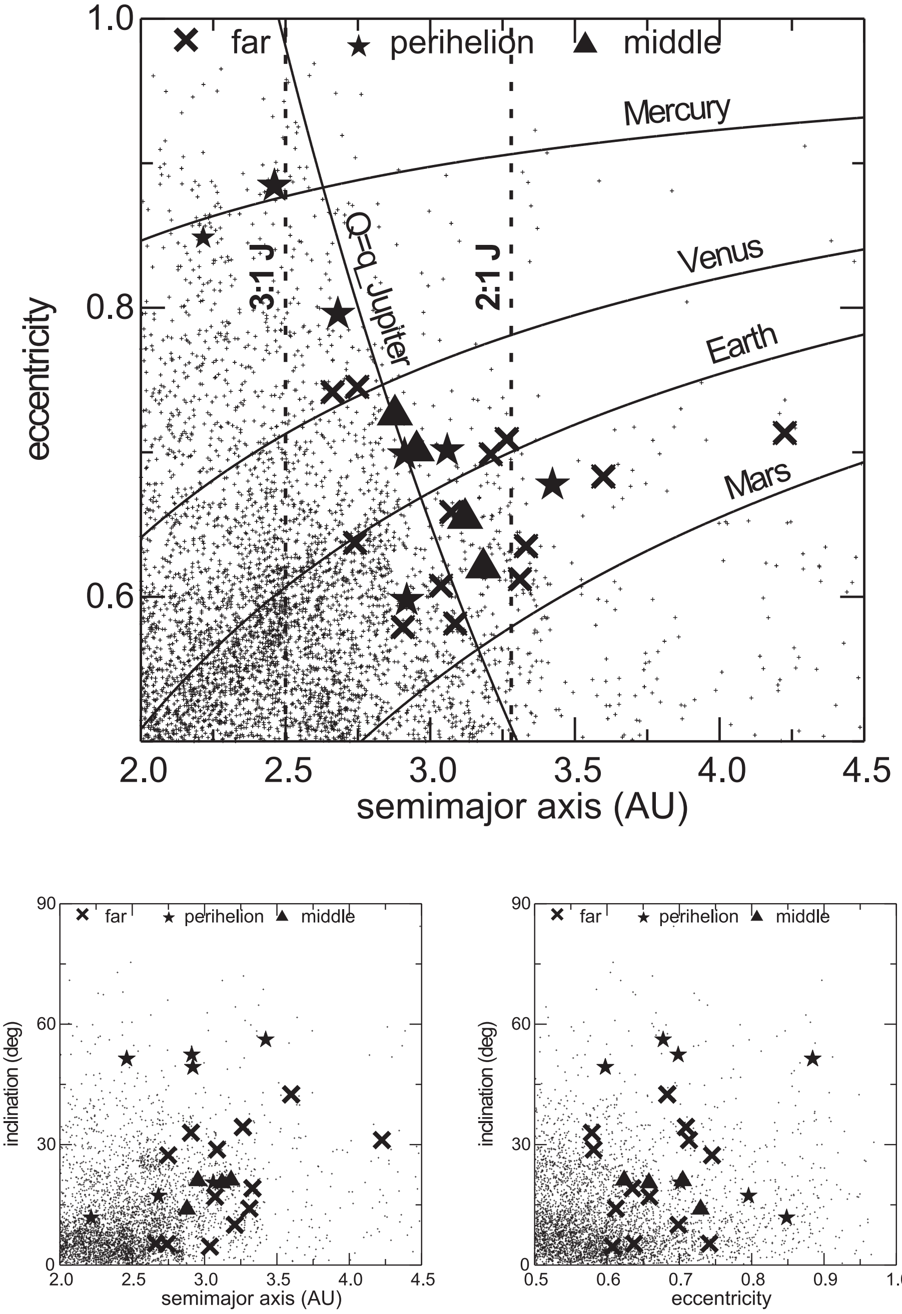


**Fig. 1.** Positions of the NEC in the *(a, e, i)* plane with their final evolution. 'Far' denotes asteroids for which the majority of clones escape the Solar System, 'perihelion' denotes clones that mainly impact the Sun, and 'middle' denotes a near equilibrium between escaping clones and those impacting the Sun. The 4282 asteroids from the Lowell data base containing 698526 orbits as of December 7, 2015 lying in the presented phase space are depicted by small crosses. In the upper panel, the mean motion resonances 3:1 and 2:1 with Jupiter are shown. Also a line with value of the aphelion of asteroids's orbits greater than the perihelion of Jupiter, together with four lines which bound the perihelion of the asteroids to the aphelion of Mercury, Venus, Earth and Mars are presented.

## 2. Horner diagram for the near-Earth comets

Fig. 1 shows results from Table 2 and Table 4 that are presented in the columns 'too far' and 'perihelion'.

The placement of the depicted lines with the planets controlling the asteroid's perihelion and the planets controlling the aphelion were based on the paper by Horner et al. (2003).

Fig. 1 presents positions of the NEC in the *(a, e, i)* plane with their final evolution. 'Far' denotes asteroids for which the majority of clones escape the Solar System, 'perihelion' denotes clones that mainly impact the Sun, and 'middle' denotes an almost equilibrium between clones escaping and impacting the Sun.

We show that most of the NECs that impact the Sun lie in the upper side of all presented panels, i.e., they have starting orbital elements eccentricity and inclination with greater values. On the other hand, objects that mainly escape our Solar System lie in the middle or bottom sides of all panels, i.e., they have smaller eccentricities and inclinations.

We observed that the majority of objects are controlled by the aphelion of Mars or the aphelion of the Earth, and by the perihelion of Jupiter. All presented NECs are located close to the 2:1 mean motion resonance (MMR) with Jupiter, and are bounded by the 3:1 MMR with Jupiter.

Note that all presented NECs have great eccentricities, $e > 0.5$ au.

## 3. Direct computations of the non-gravitational effects

Similar to the case of computing the starting orbital elements for the Swift integration in Section 2, we used the NEC observations from the International Astronomical Union Minor Planet Center (http://131.142.195.59/db_search). We also used the OrbFit software package (http://adams.dm.unipi.it/∼orbmaint/orbfit/) version 5.0 and the JPL DE431 planetary and lunar ephemerides, biased error model called 'fcct14' based on Chesley et al. (2010), with 0 and 16 additional perturbing massive asteroids, and followed the same method in the weighting and selection of observations that is being used by the NEODyS site (Farnocchia et. al (2013)). The new software also includes a debiasing and weighting scheme based on the star catalog position and proper motion corrections in asteroid astrometry by Farnocchia et al. (2015).

Next we selected the first 6 numbered NECs from Table 2 in Mommert et al. (2015) and we computed 9 virtual orbits (clones) for each NEC, $1\sigma$ uncertainty and the multiple solution method of Milani et al. (2005a, b). Using the new version 5.0 of the OrbFit software we can compute in the 7-dimensional space of the orbital elements the secular perturbation on semimajor axis called parameter $A2$. $A2$ is the non-gravitational transverse acceleration parameter in au/d$^2$ units. The parameter $A2$ is computed directly from observations.

Table 3 lists the high-precision orbital elements and their uncertainties for the first 6 numbered NECs from Table 2 in Mommert et al. (2015).

For each asteroid the first line gives the following orbital elements: $a$ – semimajor axis, $e$ – eccentricity, $i$ – inclination, $\Omega$ – longitude of the ascending node, $\omega$ – argument of perihelion, and $M$ – mean anomaly. The second line gives the rms errors of the elements and the third line gives the absolute magnitude $H$, the number of observations used and their time coverage.

The orbital elements and their ephemerides are computed together with non-gravitational parameter $A2$ without any additional massive asteroids. Parameters $A2$ are listed in Table 4.

The absolute magnitudes $H$ given in Table 3 were calculated from the observed magnitudes taking into account the computed orbit.

**Table 3.** High precision orbital elements with their uncertainties of the first six numbered NEC from Table 2. They are computed without any additional perturbing massive asteroids. The epoch: 2016 Jan. 13 (JD2457400.5).

| $a$ (au) | $e$ | $i$ (deg) | $\Omega$ (deg) | $\omega$ (deg) | $M$ (deg) |
|---|---|---|---|---|---|
| (3552) Don Quichote | | | | | |
| 4.2367244756390 | 0.7119532086087 | 31.20973506323 | 350.0170627196 | 316.8992426096 | 264.5519868926 |
| 2.44019E-07 | 3.77775E-08 | 9.34526E-06 | 1.42851E-05 | 1.46617E-05 | 2.51331E-05 |
| $H = 12.838 \pm 0.6112$ | rms=0.5747” | 658 obs. | arc: 1983 09 10.33750 – 2016 03 25.43790 | | |
| (5370) Taranis | | | | | |
| 3.329332269000 | 0.63559888748 | 19.1290891213 | 177.8434514839 | 161.2230138482 | 290.5407512361 |
| 1.15970E-07 | 1.84525E-07 | 2.03977E-05 | 3.63344E-05 | 5.59842E-05 | 7.89088E-05 |
| $H = 15.101 \pm 0.466$ | rms=0.6341” | 277 obs. | arc: 1986 08 11.30486 – 2016 03 17.55084 | | |
| (20086) 1994 LW | | | | | |
| 3.185112554250 | 0.6231281782386 | 21.7652127324 | 237.3641484671 | 57.7508985006 | 281.1659506143 |
| 5.59794E-07 | 5.43947E-08 | 1.29677E-05 | 1.90931E-05 | 4.01451E-05 | 6.77710E-05 |
| $H = 16.649 \pm 0.420$ | rms=0.6201” | 443 obs. | arc: 1994 06 03.19010 – 2011 10 31.19311 | | |
| (248590) 2006 CS | | | | | |
| 2.9107360461505 | 0.698421551580 | 52.3640619052 | 172.3985410544 | 346.4164021318 | 344.1299885825 |
| 7.11854E-08 | 1.11731E-07 | 2.43267E-05 | 3.46353E-05 | 3.71486E-05 | 1.69869E-05 |
| $H = 16.323 \pm 0.573$ | rms=0.5513” | 192 obs. | arc: 1996 06 20.27683 – 2016 02 02.04190 | | |
| (385402) 2002 WZ2 | | | | | |
| 2.461235505671 | 0.884233809269 | 51.3287281902 | 261.3640617340 | 48.1534546955 | 157.6310030995 |
| 3.93439E-07 | 1.14599E-07 | 4.21753E-05 | 1.37374E-05 | 2.84186E-05 | 8.41394E-05 |
| $H = 16.931 \pm 0.656$ | rms=0.5857” | 167 obs. | arc: 2002 11 22.55306 – 2014 01 20.23712 | | |
| (433992) 2000 HD74 | | | | | |
| 2.91857768314161 | 0.597638658139 | 49.2629830734 | 55.20001249678 | 223.5565179546 | 37.2400453345 |
| 2.92641E-08 | 2.02563E-07 | 4.50242E-05 | 7.28167E-06 | 7.46449E-05 | 1.37947E-05 |
| $H = 18.002 \pm 0.554$ | rms=0.5262” | 382 obs. | arc: 2000 04 30.38378 – 2015 06 22.72873 | | |

Computed in this way, Table 4 presents non-gravitational parameters $A2$ with their 1 $\sigma$ errors for selected asteroids without and with 16 additional perturbing asteroids.

It is evident that values of $A2$ are similar when computed with and without the additional massive asteroids.

Next we can input the parameter $A2$ computed without any additional massive asteroids as an input parameter in the OrbFit Software, and we computed starting orbital elements of clones of interesting asteroids and followed their orbital evolution.

### 3.1. Time evolution of orbital elements and close approaches with planets

Fig. 2 shows the results of 15000-year forward integrations using in the OrbFit software v. 5.0 and the JPL DE431 Ephemerides.

It is interesting that in only one case do the clones evolve around the starting position of an asteroid. It is asteroid (248590) 2006 CS. In almost all

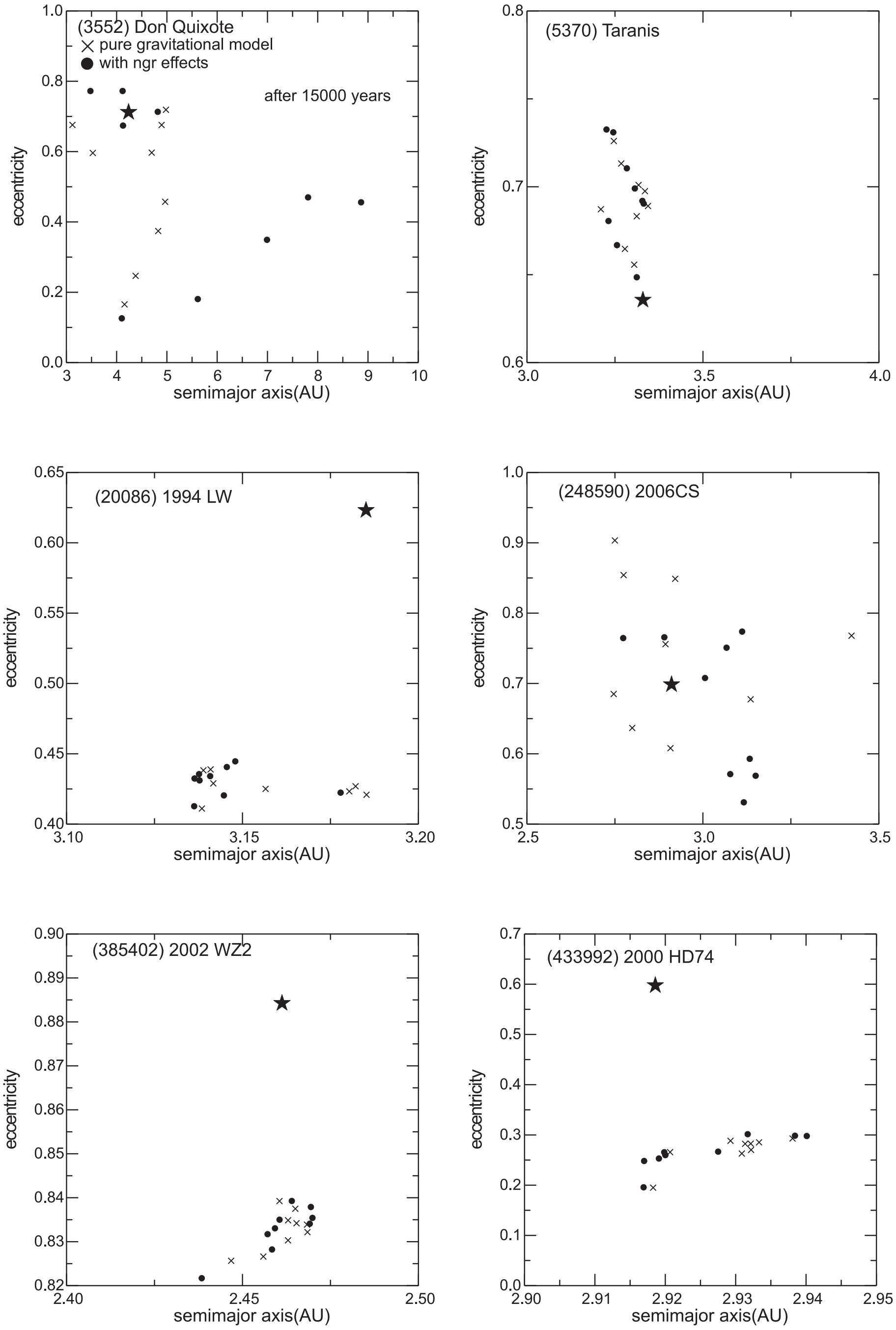


**Fig. 2.** 15000-year forward evolution of 6 selected numbered asteroids using the non-gravitational parameter $A2$ computed for 9 clones of each asteroid.

**Table 4.** Non-gravitational parameters $A2$ with their 1 $\sigma$ uncertainties for the first six numbered NECs from Table 2. They are computed without any additional perturbing massive asteroids as well as with 16 of them.

| asteroid | $D$ (km) | $A2$ for 0 asteroids (au/d$^2$) | $A2$ for 16 asteroids (au/d$^2$) |
|---|---|---|---|
| (3552) Don Quixote | 18.4 | (1.516± 3.611)E-13 | (1.095± 3.611)E-13 |
| (5370) Taranis | 5.8 | (-2.838±1.968)E-13 | (-3.005± 1.968)E-13 |
| (20086) 1994 LW | 4.8 | (-2.760± 1.168)E-12 | (-2.802± 1.168)E-12 |
| (248590) 2006 CS | 4.7 | (-2.932±1.540)E-13 | (-2.755±1.540)E-13 |
| (385402) 2002 WZ2 | 2.0 | (-0.070± 3.711)E-13 | (-0.115± 3.711)E-13 |
| (433992) 2000 HD74 | 1.4 | (-2.519±6.301)E-14 | (-7.012±6.301)E-14 |

other situations clones deviate from their starting position asteroid in phase space $(a, e)$. Hence, our selected dormant short-period near-Earth comet candidates (NECs) can significantly change their orbits and can evolve in a wide-phase space in our Solar System. However, clones computed with the Yarkovsky effect and without it after 15000 y forward integration are placed in similar $(a, e)$ phase space. The influence of the Yarkovsky effect is not visible. This is probably because of the great values of the diameters of the studied asteroids.

## Conclusion

We studied the dynamical orbital evolution of the near-Earth comets candidates (NECs) during 1 Gy forward and backward integrations without and with the Yarkovsky effect. We computed that the average dynamical half-time of these objects is about 1.5 My for forward and backward integrations, without or with the Yarkovsky effects. The mean maximum dynamical lifetime of clones of these objects is about 70 My for all studied cases.

It is interesting that clones with greater starting eccentricity values impact the Sun, and those with smaller starting eccentricities escape the Solar System.

The mean time after all clones of 23 NECs escape from integration is about 64.3/65.3 My in forward/backward integrations using the pure gravitational model of Solar System, and 75.1/61.7 My using the non-gravitational Yarkovsky effect, respectively.

We also computed the half-time of the NECs, i.e., the time when only 50% of clones are in our model of integration. Suitable values are 1.198/1.536 My and 1.419/0.710 My for the NECs.

It appears that the behavior of the NECs during integration, i.e., escaping from the Solar System or falling into the Sun, depends on the placement of these objects in the *(a, e, i)* phase-space. Moreover, our selected dormant short-period near-Earth comet candidates (NECs) can significantly change their orbits and can evolve in wide-phase space in our Solar System.

It is worth noting that active comets are mostly affected by cometary non-gravitational effects, which are orders of magnitude larger than the Yarkovsky effect. Moreover, the physics of the Yarkovsky effect probably do not work in the same way for active comets. On the other hand, for near-Earth comet candidates, the Yarkovsky effect might make sense. However, the Yarkovsky effect can be important for high-precision ephemerides not for long-term evolution, unless it is feeding a resonance. Moreover, this is not the case of a near-Earth object whose dynamical evolution is dominated by planetary encounters. Finally, the Yarkovsky effect depends on the physical properties of the object, most of which are unknown. Our work is only the first approximation of including non-gravitational effects in motion of dormant short-period near-Earth comet candidates.

Future observations of the physical parameters of NECs will help us to better understand their orbital evolution.

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