POSSIBLE IMPACTS OF THE ASTEROID (99942) APOPHIS. Ireneusz Wlodarczyk, Chorzow Astronomical Observatory, e-mail: astrobit@ka.onet.pl.

Introduction: We present computations of updated possible collisions of the asteroid (99942) Apophis with the Earth based on its all published observations. Earlier, in [1] we presented the current state of calculations of possible collisions for all the so-called Special NEAs.

Computation method: We based the computation on the published observations and the starting orbit from the NEDyS on August 8, 2020 (https://newton.spacedys.com/neodys/index.php?pc=1.1.0&n=99942), i.e. based on 4523 optical observations and 46 radar over interval: 2004 03 15.10789 - 2020 06 08.18194 (https://minorplanetcenter.net/iau//mpc.html).

To compute the possible collisions of Apophis with the Earth, we used the publicly available Orb-Fit v. 5.0.5 and 5.0.6 software. Both versions can compute orbits and search for possible impacts with the Earth using dynamical parameters connected to the non-gravitational perturbations. In the case of Apophis, we used the non-gravitational parameter A2. Using OrbFit v.5.0.5, we used the error model 'fcct14' described in [2] and in [3]. In v5.0.6, we used the error model 'vftc17' according to [4].

To compute possible Apophis collisions with the Earth, we integrated the equation of motions until JD2490600.0 TDT. We used the parameter $\sigma\_LOV = 5$ and calculated 2401 clones (VAs). We used the JPL DE431 Solar System model along with an additional 17 massive asteroids as described in [5] and in [6].

We used the selection and weighting of observations according to the NEODyS site given above.

Results of computation:

	No. of observations:	
Error models:	fcct14	vftc17
total	= 4569	4569
selected	= 4537	4565
rejected	= 0	0
recovered	= 0	0

Table 1. Keplerian elements, epoch JD2459000.0 TDT

Error models: fcct14/vftc17
RMS=0.32641”/0.27922”
a=(0.9225707138 +/ 1.43E-08) au
(0.9225707320 +/- 1.17E-08) au
e=0.19147473524 +/- 6.19E-09
0.19147472916 +/- 5.86E-09
i=(3.336855182 +/- 3.48E-07) deg
(3.336855201 +/- 4.28E-07) deg
Ω=(204.0484016 +/- 2.17E-05) deg
(204.0483880 +/- 2.72E-05) deg
ω=(126.6869505 +/- 2.12E-05) deg
(126.6869644 +/- 2.65E-05) deg
M=(248.1483255 +/- 4.73E-05) deg
(248.1482643 +/- 3.89E-05) deg
A2=(5.0944 +/-2.7166)E-14 au/d^2
(1.6430 +/- 2.2294)E-14 au/d^2

where *a* denotes semimajor axis, *e* – eccentricity, *i* – inclination, *Ω* - longitude of ascending node, *ω* - the argument of perihelion, *M* - mean anomaly, and *A2* - non-gravitational transverse acceleration parameter.

Table 2. Close approach with the Earth in 2029

error model	date	distance [au]	distance [km]
fcct14	2029/04/13.90704	0.0002525	37800
vftc17	2029/04/13.90712	0.0002550	38000

Table 2. Impact risk table for fcct14 error model

date YYYY/MM	*σ_LOV*	*p_RE*	*Exp. En.* MT	*PS*
2036/04/13.371	-3.285	3.71E-06	2.81E-03	-2.80
2042/04/13.715	-3.329	9.55E-09	7.25E-06	-5.53
2044/04/13.295	-3.217	7.63E-09	5.79E-06	-5.67
2053/04/12.915	-3.236	2.18E-08	1.65E-05	-5.35
2062/04/13.372	-3.237	6.08E-10	4.61E-07	-7.01
2068/04/12.634	1.111	8.03E-07	6.09E-04	-3.95
*2069/10/15.596	3.614	4.27E-10	3.24E-07	-7.24
*2069/10/15.972	4.030	5.23E-10	3.97E-07	-7.15
2075/04/13.327	-3.088	2.27E-09	1.72E-06	-6.56
2076/04/12.696	1.129	1.71E-07	1.29E-04	-4.69

where *σ_LOV* denotes the position along the line of variation, *LOV*, in the *σ* space and values of σ are here in the interval [-5,5],

Table 2 presents also probability of Earth impact (*p_RE*) and Palermo Scale (*PS*). *PS* is the new hazard scale [7] . Expected energy (*Exp. En.*) denotes impact energy multiplied by impact probability. Units are in megatons MT (1 MT=4.184E15 J).

Also, we found that 749 VAs from all 2401 computed VAs has nongraviational parameter *A2*>0 au/d^2. They have a possible collision with the Earth only in 2069 as is marked by a star in Table 2.

We have not detected any possible impacts using the ‘vftc17’ error model and the OrbFit v. 5.0.6. Also using the different sampling methods of the *LOV*: *LOV1* – with constant step in *σ*, and *LOV2* – with constant step in the *impact probability, IP* [8], [9].

Summary:

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References:

[1] Wlodarczyk I. (2020) *BlgAJ, 32,* 27. [2] Chesley S. et al. (2010) *Icarus*, 210, 158. [3] Farnocchia D. et al. (2015) *Icarus*, 245, 94. [4] Veres P. et al. (2017), *Icarus*, 296, 139. [5] del Vigna et al. (2018) *A&A*, 617, A61. [6] Farnocchia, D. (2013), *Icarus*, 224,1. [7] Chesley et al. (2002), *Icarus,* 159, 423. [8] del Vigna et al. (2019), *Icarus*, 321, 647. [9] Wlodarczyk, I. (2019), *OAst*, 28, 180.