POSSIBLE IMPACTS OF THE ASTEROID (99942) APOPHIS.

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Based on all published observations, we present computations of possible collisions of the asteroid (99942) Apophis with the Earth.
In [1], we presented the current state of our computations of possible collisions for all the so-called Special NEAs.
We based the computation on the published 4672 optical observations and 46 radar over interval: 2004 03 15.10789 - 2021 01 02.55591: (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. We computed the non-gravitational parameter A2. In the OrbFit v.5.0.5, we used the error model 'fcct14' , in v5.0.6, we used the error model 'vftc17' [2,3,4].

To compute possible Apophis collisions with the Earth, we integrated the equation of motions until JD2490000.0 TDT, i.e., to 2105-April-16.0. We used the parameter s_LOV = 5 and calculated 2401 clones (VAs). We used the JPL DE431 Solar System model along with an additional four first numbered asteroids and 17 massive asteroids or without any additional perturbing asteroids [5,6].

Table 1. Impact risk table for fcct14 error model

date	σ_LOV	p_RE	Exp. En.	PS
YYYY/MM			MT	
Case A: 0 additional perturbing asteroids				
fct14: A2=(-3.165+/-1.369)E-14 au/d^2				
vfcc17: A2=(-3.182+/-0.758)E-14 au/d^2				
2068/04/12.632	0.793	2.32E-06	1.76E-03	-3.49
2068/10/15.324	2.499	1.62E-08	1.23E-05	-5.65
Case B: 4 additional perturbing asteroids				
fct14: (-3.159+/-1.369)E-14 au/d^2				
vfcc17: A2=(-3.177+/-0.758)E-14 au/d^2				
2068/04/12.632	0.792	2.26E-06	1.71E-03	-3.50
2068/10/15.326	2.499	1.57E-08	1.19E-05	-5.66
Case C:17 additional perturbing asteroids				
fct14: A2=(-3.158+/-1.369)E-14 au/d^2				
vfcc17: A2=(-3.177+/-0.758)E-14 au/d^2				
2056/04/13.096	0.716	2.29E-07	1.74E-04	-4.37
2068/04/12.637	0.791	3.42E-06	2.60E-03	-3.32

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 1 presents also the 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).
Additionally, 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 sigma, and LOV2 - with constant step in the impact probability, IP [8], [9].
Also, in Table 2., we computed different close approaches of Apophis in 2021 and 2029 for different cases.

Table 2. Close approaches of Apophis with the Earths.

Orb-Fit v. 5.0.5., fct14

0 additional perturbing asteroid

2021/03/06.05179 0.11265137 au

2029/04/13.90709 0.00025393 au

Four additional perturbing asteroids

2021/03/06.05181 0.11265135 au

2029/04/13.90708 0.00025378 au

17 additional perturbing asteroids

2021/03/06.05181 0.11265135 au

2029/04/13.90708 0.00025378 au

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.