

POSSIBLE IMPACTS OF THE ASTEROID (101955) BENNU. Ireneusz Włodarczyk, Chorzow Astronomical Observatory, e-mail: astrobit@ka.onet.pl.

Introduction: We present computations of possible collisions of the asteroid (101955) Bennu with the Earth, based on 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 589 optical observations and 29 radar over interval: 1999 Sept. 11.40624 – 2018 May 15.78855: (<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' described in [2] and in [3], in v5.0.6, we used the error model 'vftc17' according to [4].

To compute possible Bennu collisions with the Earth, we integrated the equation of motions until JD2518285.5 TDT, i.e. to 2182-September-24.0. We used the parameter $\sigma_{LOV} = 5$ and calculated 2401 clones (VAs). We used the JPL DE431 Solar System model along with an additional 4 first numbered asteroids and 17 massive asteroids as described in [5] and in [6], or without any of additional perturbing asteroids.

We used the selection and weighting of observations according to the NEODyS site: <https://newton.spacedys.com/neodys/>.

Results: Table 1. Impact risk table for fcct14 error model

date YYYY/MM	σ_{LOV}	p_{RE}	Exp. En.	PS MT
Case A: 0 additional perturbing asteroids				
fcct14: A2=(-4.495+/-0.023)E-14 au/d^2				
vftc17: A2=(-4.489+/-0.024)E-14 au/d^2				
2175/09/25.156 0.266 1.01E-05 4.36E-02 -2.76				
2175/09/25.161 0.580 5.98E-05 2.58E-01 -1.98				
2176/09/24.390 1.796 2.72E-05 1.18E-01 -2.33				
2180/09/24.392 0.305 1.38E-05 5.98E-02 -2.63				
2180/09/24.351 0.095 1.22E-05 5.26E-02 -2.69				
2181/09/24.618 0.233 2.05E-07 8.88E-04 -4.46				
2181/09/24.560 0.264 1.60E-07 6.93E-04 -4.57				
2181/09/24.565 1.158 1.43E-06 6.21E-03 -3.62				
2181/09/24.539 2.878 4.20E-08 1.82E-04 -5.15				
2182/09/24.859 -3.866 4.52E-08 1.95E-04 -5.12				
2182/09/24.854 -3.364 3.49E-07 1.51E-03 -4.24				
Case B: 4 additional perturbing asteroids				

fct14: A2=(-4.547+/-0.024)E-14 au/d^2
vftc17: A2=(-4.542+/-0.024)E-14 au/d^2
2175/09/25.158 0.518 6.84E-06 2.96E-02 -2.92
2175/09/25.156 0.831 9.52E-05 4.12E-01 -1.78
2176/09/24.389 2.048 9.25E-06 4.01E-02 -2.80
2180/09/24.409 -0.053 5.95E-06 2.57E-02 -3.00
2180/09/24.351 0.347 1.22E-05 5.26E-02 -2.69
2181/09/24.619 0.485 4.21E-07 1.82E-03 -4.15
2181/09/24.553 0.850 1.89E-06 8.18E-03 -3.50
2181/09/24.566 1.410 8.52E-07 3.69E-03 -3.85
2181/09/24.541 3.130 2.87E-08 1.24E-04 -5.32
2182/09/24.857 -3.614 5.25E-08 2.27E-04 -5.06
2182/09/24.849 -3.112 2.62E-07 1.13E-03 -4.36
Case C: 17 additional perturbing asteroids
fct14: A2=(-4.546+/-0.024)E-14 au/d^2
vftc17: A2=(-4.540+/-0.024)E-14 au/d^2
2175/09/25.169 0.460 3.53E-06 1.53E-02 -3.21
2175/09/25.154 0.773 4.95E-05 2.14E-01 -2.06
2176/09/24.394 1.989 3.00E-06 1.30E-02 -3.28
2180/09/24.406 -0.111 5.65E-06 2.44E-02 -3.02
2180/09/24.359 0.289 5.04E-06 2.18E-02 -3.07
2181/09/24.619 0.426 3.28E-07 1.42E-03 -4.26
2181/09/24.570 0.791 1.46E-06 6.30E-03 -3.61
2181/09/24.535 3.071 2.00E-08 8.67E-05 -5.47
2182/09/24.859 -3.672 7.39E-08 3.20E-04 -4.91
2182/09/24.850 -3.171 1.94E-07 8.41E-04 -4.49

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).

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 : LOV_1 – with constant step in σ , and LOV_2 – with constant step in the *impact probability*, IP [8], [9].

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References: [1] Włodarczyk 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] Włodarczyk, I. (2019), *OAst*, 28, 180.