

The potentially dangerous asteroid (99942) Apophis

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We computed impact solution of the potentially dangerous asteroid (99942) Apophis for 2068. Our computations are based on 4022 optical observations and seven radar observations from 2013 March 15.10789 UTC through March 28.089569 UTC. We used the freely available OrbFit software package.

1 Introduction

The potentially dangerous asteroid (99942) Apophis was discovered on June 19, 2004 at the (IAU 695) Kitt Peak Observatory by F. Bernardi, D. J. Tholen, and R. A. Tucker. Asteroid (99942) Apophis belongs to the Aten group which contains 779 members as of May 27, 2013 and is one of 9858 known Near-Earth Asteroids at this time (<http://www.minorplanetcenter.net/iau/lists/Unusual.html>). Also Apophis belongs to one of 1401 Potentially Hazardous Asteroid (PHA) (<http://www.minorplanetcenter.net/iau/lists/Dangerous.html>).

The JPL NASA Sentry Risk Table (<http://neo.jpl.nasa.gov/risk/>) lists, as of May 27, 2013, 438 Near Earth Asteroids which are potentially dangerous. Sentry is the JPL NASA automated collision monitoring system that computes possibilities of future impact of observed asteroids with the Earth over the next 100 years. Apophis has 10 years observational arc and is still in this Table from 2004 year. Now it is in the Table with the objects not recently observed. From 2004 there are published many papers with many listed possible impacts computed with different methods: Farnocchia et al. (2013), Królikowska et al. (2009), Włodarczyk (2008), Włodarczyk (2013) and many others.

2 Method and Results

The asteroid possible impact solutions are usually presented in a form such as that used by the NASA's Impact Risk Page (<http://neo.jpl.nasa.gov/risk/>) or by the NEODYs (<http://newton.dm.unipi.it/neody/index.php?pc=4.1>).

They list the name of each dangerous asteroid, the dates of its potential impacts, the probability of possible impact at each date and the impact energy. Generally, the OrbFit software searches for possible impacts and give these *standard* solutions.

Computations were made using the free OrbFit Software Package (<http://adams.dm.unipi.it/~orbmaint/orbfit/>). We are taking into account the JPL DE405, perturbations of additional 25 massive asteroids, weighting methods and selection of observations according to the NEODYs, error model based on Chesley et al. (2010) and the Yarkovsky effects.

Asteroid (99942) Apophis has 10 years observational arc so it is possible to compute non-gravitational parameter da/dt with the method given by Milani et al. (2009) for asteroid (101955) 1999 RQ36. The value of da/dt computed by us is $da/dt = -1.17 \times 10^{-4}$ AU/Myr.

Our method of computing possible impact orbits Włodarczyk (2007) is based on the method of Milani included in the OrbFit software where the *covariance cloning* is based on the line of variations (LOV) with the largest eigenvalue, where σ_{LOV} denotes the position of an asteroid on the orbit along the line of variations in σ space (Milani et al., 2005).

We searched for potential impacts out to $\sigma_{\text{LOV}} = \pm 5$ similarly to the Sentry System of the JPL NASA. Moreover, we computed 14999 virtual asteroids (VAs) on both sides of the LOV. It gives 29998 VAs. Hence, we find six possible impacts in 2068, 2086 - twice, 2105, 2108 and 2110.

We find possible impact of VA#2670 in 2068/10/15.325.

Table 1 lists orbital elements of impact orbit #2670 together with uncertainties. Table 2 present details of the possible impact.

Table 1: Apophis. Starting orbit for impact in 2068 with non-gravitational parameter $da/dt = -1.17 \times 10^{-4}$ AU/Myr. Epoch JD2456400.5=2013-Apr-18.

semimajor axis (au)	0.922086506819890	1.64191E-10
eccentricity	0.191164753338685	1.56870E-08
inclination (deg)	3.3305676771358	4.50549E-07
the longitude of the ascending node (deg)	204.2238137503066	2.22241E-05
argument of perihelion (deg)	126.4571501148232	2.23091E-05
mean anomaly (deg)	235.4685001470080	5.34046E-06

Table 2: Apophis. Possible impact solutions for the year 2068 using computed parameter $da/dt = -1.17 \times 10^{-4}$ AU/Myr.

Impact probability	5.78360E-9
Mass	2.10E+10 kg
Impact velocity	12.61 km/s
Energy	3.98E+2 MT
Date of impact	2068/10/15.325
σ_{LOV}	3.75682

Table 2 lists possible impact solutions for the year 2068 using computed non-gravitational parameter $da/dt = -1.17 \times 10^{-4}$ AU/Myr connected with the Yarkovsky effect.

Our computations are based on 4022 optical observations and 7 radar observations of the asteroid (99942) Apophis from March 15.10789 UTC through March 28.089569 UTC, 2013. The asteroid (99942) Apophis will be observable for many years so new optical and radar observations can refine the orbit of the asteroid. Hence we will compute more precisely possible impacts solutions or Apophis will disappear from the list of the potentially dangerous asteroids.

References

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