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Asteroid Apophis orbit from recent observations

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Abstract

Since its discovery in 2004, asteroid (99942) Apophis previously designed 2004 MN4 became a study case. It was the first asteroid who reached level 4 on Torino Scale for a possible collision with the Earth in 2029. The last observations for Apophis were made in 2008 and the last results conclude on a collision probability of 1/250000 for the 2036-threat.
Recent observations were made at Pic du Midi Observatory (France) and at Magdalena Ridge Observatory (New Mexico). We propose here an update of Apophis's orbit and the new predictions of encounters with Earth taking into account the Yarkovsky effect and stellar catalogue biases.

1. Introduction

Asteroid 99942 Apophis (previously designed 2004 MN4) was first discovered in June 2004 by R. Tucker, D. Thollen and F. Bernardi. After being lost, it has been rediscovered in December 2004 and since those first observations, Apophis was revealed to be a potential threat for the Earth. As a matter of fact, it reached the level 4 of Torino Scale with an impact probability with the Earth in 2029 estimated around 1/37 ($\sim$ 2.7 %). After radar observations made in January 2005, the 2029-threat became a deep close encounter ($\sim 5.6\,R_\oplus$) but an other threat due to the 2036-resonant return appeared. At the date of October 7th 2009, the impact probability for this date was estimated to 1/250000.

2. Recent observations

2.1 Observations

New observations of Apophis were first made at Pic du Midi (in the French Pyrenean mountains). 69 observations spanning 4-7th March 2011 were provided using a 1 meter telescope. Apophis appears in the sky with a very faint magnitude ($\sim$ 21). Figure1 shows Apophis in the sky of Pic du Midi observatory on March, 7 2011.

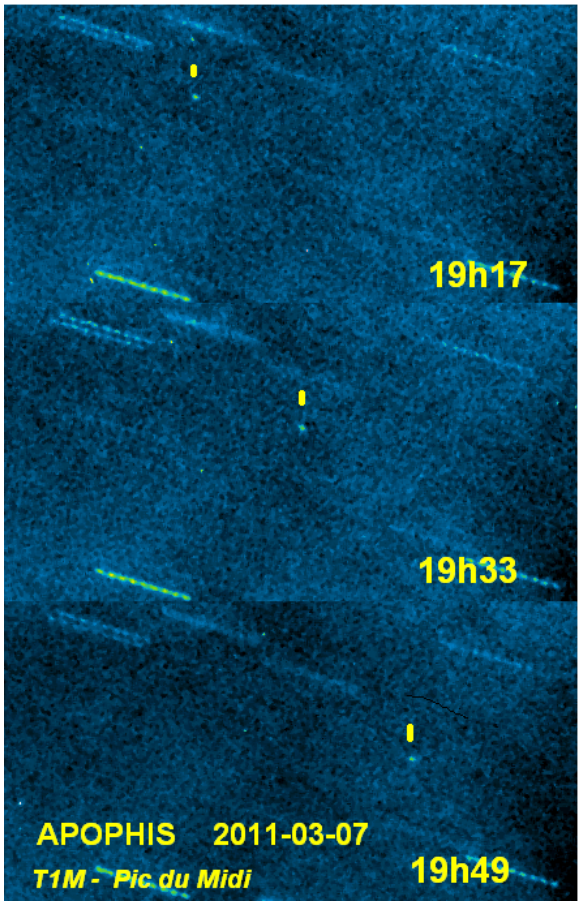

Figure 1: Asteroid Apophis in the sky of Pic du Midi on March, 7 2011.

One week later, the Magdalena Ridge Observatory (in the Magdalena mountains) made 4 observations covering a 30 minutes arc data with a 2.4 meters telescope. Combining all previous data available at the Minor Planet Center (MPC) and all the recent observations, a fit was done using OrbFit 4.0 package [1].

Figure 2 shows the postfit residual in right ascension and declination.

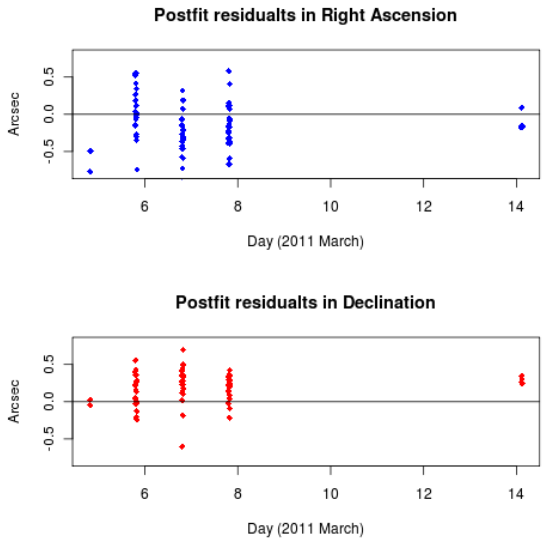

Figure 2: Postfit residual in right ascension and declination (in Arcsec) for Pic du Midi and Magalena Ridge observations.

2.2 Results

The first main result obtained was a new estimated close-approach distance beetween Apophis and the Earth in 2029. The asteroid is now estimated to pass by 600 km further than the previous estimated distance. As a consequence, the asteroid seems to go away from the 2036-keyhole and come closer to the 2037-keyhole (see Tab.1)

Table 1: Distance between the center of the 2036 and 2037 keyholes and the center of the 3σ ellipse uncertainty in the 2029-target plane with and without march observations.

Keyhole	Without March obs	With March obs
2036	1181 km	1781 km
2037	2476 km	1875 km

However, the Yarkovsky effect is the main non-gravitational effect affecting NEAs orbit. Its main consequence is a secular drift on the semimajor axis. Because this effect depends on physical parameters (which are mostly unknown), we can only put in evidence a statistical influence of the Yarkovsky effect on both 3σ ellipse uncertainty in the 2029-target plane and distance of keyholes (primary or secondary) from the ellipse's center. Th effect of Yarkovsky acceleration has already been studied in [2].
Moreover, Chesley et al. in [3] put in evidence some biases in stellar catalogues. The authors thus propose two debiasing method: a debias method from indirect reference to postfit astrometric residuals and a debiased method from direct reference star catalogs.
The update orbit of Apophis proposes in this study will also take into account those debias methods.

3. Summary and Conclusions

Apophis will be the most famous Potentially Hazardous Asteroids for many decades. Its unparticular orbit made him a good case for close encounters, impact probabilities and keyholes study. However, asteroid Apophis's main uncertainties are due to the Yarkovsky effect. Not enought physical parameters are known in order to well quantify its influence. The most important parameter to be determined is the spin obliquity which will be settled with future radar observations in 2013 and 2021.

Acknowledgements

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References

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[3] Chesley, S.R., Baer, J., and Monet, D.G.: Treatment of star catalog biases in asteroid astrometric observations, Icarus, Vol. 210, pp. 158-181, 2010.