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Close encounters among asteroids, comets, Earth-Moon system and inner planets: the cases of (99942) Apophis and Comet C/2013 A1

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Abstract. Graphical studies on the orbits of the Potentially Hazardous Asteroid (99942) Apophis and Comet C/2013 A1 are presented.

1. Introduction

Asteroid (99942) Apophis, Greek name of *Apep*, the Egyptian god of evil and destruction, is currently the most dangerous object in terms of likelihood of impact. Discovered by R.A. Tucker, D.J. Tholen and F. Bernardi on June 19, 2004 at Kitt Peak Observatory, it was lost after only two consecutive nights. When re-observed by G. Garrad from Siding Spring in Australia on December 18, 2004, it become soon clear that 2004 MN4 (as provisionally designated) could be a real threat for our planet. For the end of 2004 a preliminary computation assesed a risk of an impact in 2029 of at least 3%. Fortunately this probability decreased gradually to zero when new astrometric positions became available. In order to show graphically the geometrical circumstances of such encounter we computed, using ORBFIT software package (release 4.2), an orbit which includes all the observations (optical and radar) from March 15, 2004 to February 26, 2014. Then we analyzed the asteroid orbital evolution until its close encounter with the Earth on April 13, 2029 and our Moon on April 14. All the data were then displayed by a dedicated graphical software developed at Sormano Observatory (Testa 1992) to plot a series of diagrams highlighting the asteroid motion during its close approach to the Earth-Moon System. According to these results Apophis will pass at a minimum nominal distance of 38315 km (about 32000 km above the Earth's surface) on April 13, 2029 at 21^{h} 45.1^{m} UT. Owing to strong perturbations from both Earth and Moon, soon after this encounter Apophis will undergo a change in its dynamical classification from Aten to Apollo, its period of revolution becoming longer than one year and its semimajor axis larger than 1 AU.

As shown in figures 1 and 2, Apophis will reach the Earth-MOID point at 21^{h} 53.2^{m}, just 21 minutes later than our planet and about 8 minutes after its closest approach. Figure 3 shows the minor planet crossing the Earth-Moon system, reaching a minimum separation of about 95200 km from our satellite on April 14, at 14^{h} 34^{m} UT.

Finally in figure 4 we have analyzed Apophis Earth-MOID variation between 1950 and 2060 (Manca 2014). From the beginning of this century until 2060 this parameter remains within 0.0006 A.U. with its lowest values in

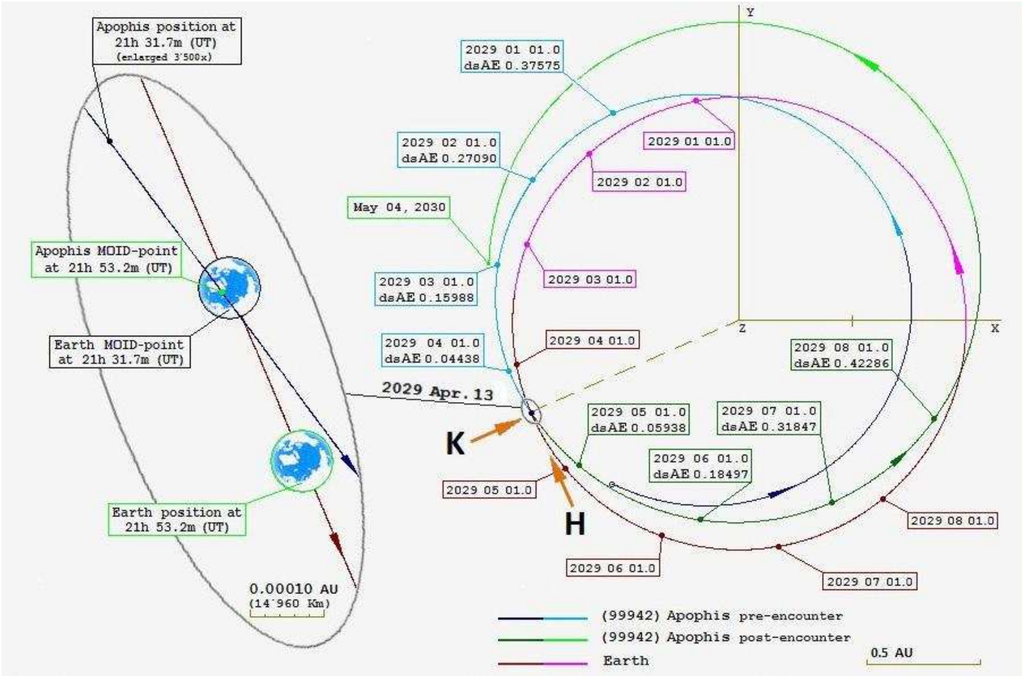

Fig. 1. Paths of Apophis and the Earth from June 23, 2008 to May 04, 2030 (North Ecliptic Pole view).

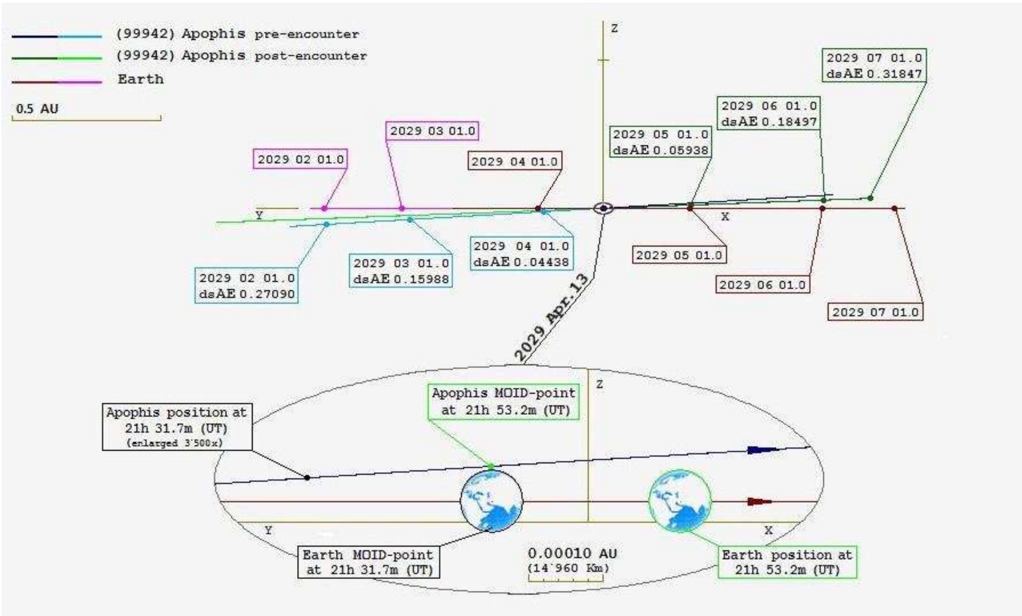

Fig. 2. Paths of Apophis and the Earth from June 23, 2008 to May 04, 2030 (Ecliptic Plane view).

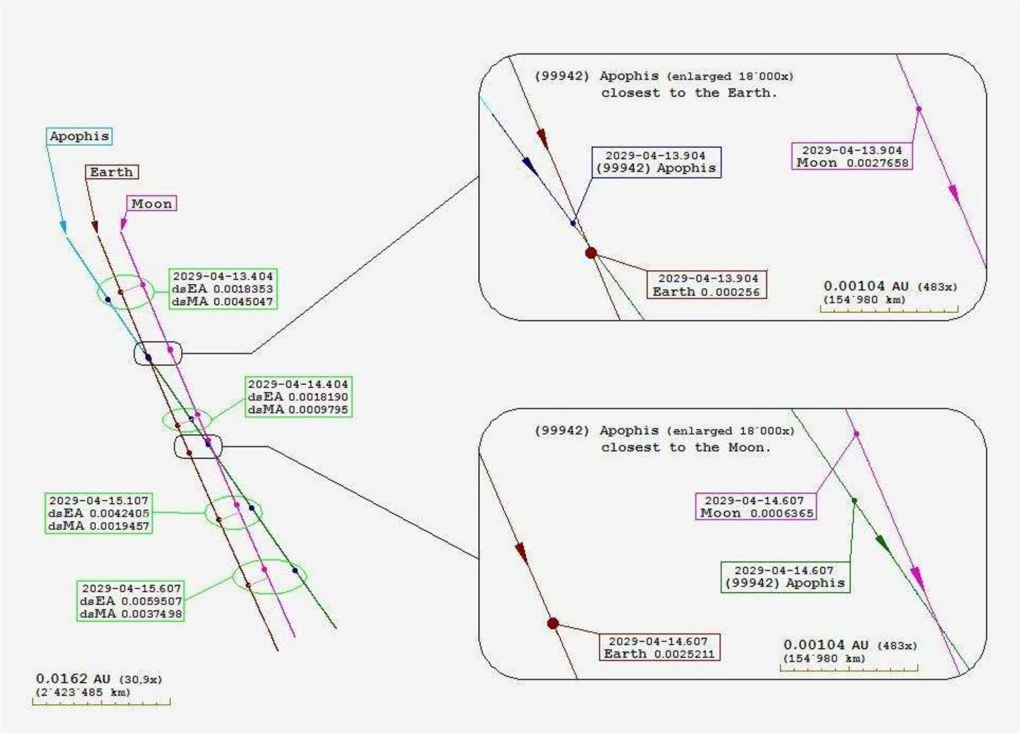

Fig. 3. At left: Apophis from April 13 to April 15, 2029 through the Earth-Moon System. At right: positions of Earth, Moon and asteroid at the time of their closest approach.

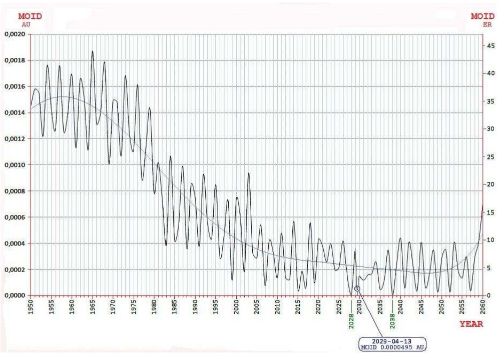

Fig. 4. Apophis Earth-MOID variation between 1950 and 2060.

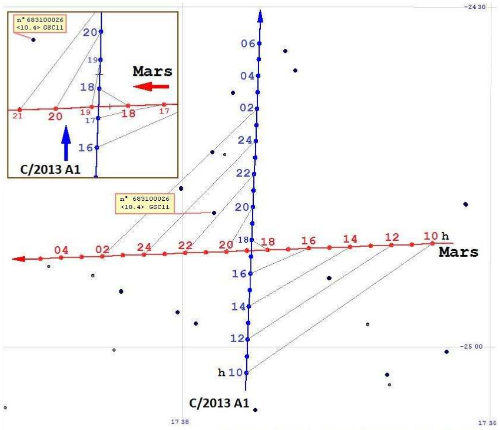

Fig. 5. Close encounter between C/2013 A1 and Mars on October 19, 2014. The separation angle is 97.6 arcsec (Earth view).

2028 and 2038, when it will reach 0.2 Earth radii.

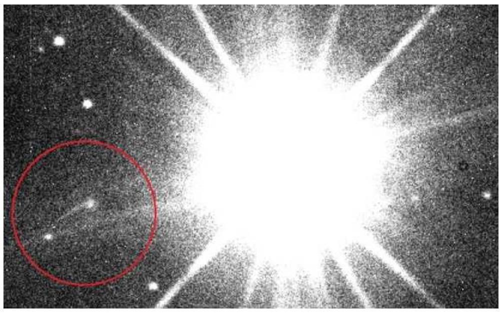

Fig. 6. CCD image of Comet C/2013 A1 and Mars from Sormano Observatory on October 19, 2014.

2. Comet C/2013 A1

Comet C/2013 A1 was discovered on January 3, 2013 by R.H. McNaught on CCD images taken at Siding Spring Observatory with the 0.5 m Uppsala Schmidt telescope. At first classified as an asteroid, during the follow-up observations revealed its cometary nature, showing a faint tail. Thanks to pre-discovery images dated December 4 and 8, 2012, obtained respectively by Pan-STARSS and Catalina Sky Survey, a preliminary orbit was computed. On February 25 a russian amateur astronomer, Leonid Elenin, drew attention to the fact that a collision between this comet and Mars on Oct 2014 could not be excluded, since his first computation indicated a minimum distance of 0.00073 AU (about 109200 km). More precise orbital parameters available in the following weeks and months confirmed such encounter but ruled out the possibility of any impact.

On the basis of 771 observations from October 4, 2012 to August 11, 2014 we calculated a minimum nominal planetocentric distance of 134638 km on October 19, 2014 at 18:32 UT, an approach that made the comet one of the brightest object in the martian sky. Figure 5 shows in detail our predictions (Earth view), which we used to plan observation from Sormano Observatory.

As expected, the observation was actually a quite difficult task, mainly due to the difference in brightness between the comet and Mars, but also because the objects were visible just for one hour, very low above the local horizon.

For more information please visit Sormano Observatory web pages:
`http://www.brera.mi.astro.it/sormano/Apophis/Sormano_Apophis.html` and
`http://www.brera.mi.astro.it/sormano/C2013A1/C2013A1.html`.

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