Meteorite producing fragment on the Apophis' orbit

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A meteorite producing object moving along the orbit almost coinciding with that of the Apophis asteroid (99942) was found. The object may be a Apophis' fragment. It is shown, that the Apophis' orbit has approaches to the Earth's orbit (up to the indicated limit of $\rho \leq 0.20$ AU) within a long time interval.

1 Introduction

Apophis (99942) is, as known, a potentially hazardous asteroid for the Earth. Its next approach to the Earth is expected on 13 April 2029 for the geocentric distance[1] of 0.0002561 AU. Apophis' diameter makes up approximately[2] 0.325 km. Apophis is an Sq-class asteroid and most closely resembles *LL* ordinary chondrite meteorites in terms of spectral and mineralogical characteristics (Binzel et al., 2009).

Defining Apophis' place in the system of meteor bodies, one should refer it to the Cyclids' system (Terentjeva and Barabanov, 2011). Meteor bodies of the Cyclids move along the orbits almost coinciding with the Earth's orbit ($e \leq 0.14$, $q' \leq 1.2$ AU, $i \leq 15°$). All elements of the Apophis' orbit lie within limits of changes in elements of the Cyclids' orbits, differing only for an insignificant value of 0.05 in the eccentricity.

2 Results and conclusions

When studying the interrelation of various populations of minor bodies in the Solar System (asteroids, comets, meteor streams, large meteor bodies – including meteorites, possible genetic relations in the families within the minor bodies complex), Terentjeva (1989) has found a population of 39 meteorite producing objects. Results of photographic observations of 379 bright fireballs of the Prairie and European networks were analyzed (McCrosky et al., 1976, 1978; Ceplecha, 1978). This population included objects for which the estimated terminal mass was $^1/_4$ kg and more. All 39 objects of this population are essentially meteorites and could be found. The above work provides a Table (and *Figure 1*), containing a total of 39 orbits along which meteorite producing bodies with extra-atmospheric masses M_∞ from several kilograms to about thirty tons moved. Orbit (No. 14) of the meteorite producing object, which is almost identical to that of the Apophis asteroid, was found within this population of bodies, coordinates of radiants coincide perfectly (*Table 1*). Extra-atmospheric mass of the object $M_\infty = 1.2$ kg.

Concerning the 1950 .0 equinox in *Table 1* one should note the following. The accuracy of the determination of radiant coordinates by means of photographic observations varies on average from several arcseconds to 3°, in velocity – from 0.1 to 3%. For the interval of 75 years (for example from W.F. Denning' Epoch 1875.0 to 1950.0) the difference caused by precession makes about 1°, which is not essential taking into account the accuracy of meteor data (Terentjeva, 1966). In our case for the interval of 50 years (1950.0 – 2000.0) this value will be less than 1°.

We (Terentjeva and Barabanov, 2011) calculated the approaches of the Apophis' orbit to the Earth's orbit and the theoretical geocentric radiants in all points of approach (up to the distance of $\rho \leq 0.20$ AU). The study is based on the following system of the Apophis' elements (Shor, 2009):

$a = 0.922$ AU	$\omega = 126.41858°$
$e = 0.1911107$	$\Omega = 204.43196°$
$q = 0.746$ AU	$i = 3.33172°$

The orbital elements of Apophis are given for the 2000.0 equinox.

The latest determination of the Apophis' orbit[3] is different from the one above in the following way: $\Delta a = 0.00028$ AU, $\Delta e = 0.000037$, $\Delta\omega = 0.023°$, $\Delta\Omega = 0.025°$, $\Delta i = 0.00044°$, which is not essential while comparing it to meteor orbits (considering their low accuracy).

Apophis' orbit turned out to have approaches to the Earth's orbit on the major part of its orbit (except for a perihelion area at 117° in true anomaly) within a long 8-month period. There are two points of closest approach of the Apophis' orbit with the Earth's orbit (two appulses): in the region of the orbit's ascending node of April 13 ($\lambda_\odot$=24. 144°, equinox 2000.0) with $\rho = 0.000307$ AU and in the region of the descending node of December 20 ($\lambda_\odot$=268.736°, equinox 2000.0) with $\rho = 0.0520$ AU.

[1] http://www.ssd.jpl.nasa.gov/
[2] http://www.esa.int

[3] http://www.ssd.jpl.nasa.gov/

Table 1 – Asteroid (99942) Apophis and meteorite producing fragment. Orbital elements of the asteroid Apophis are given for the 2000.0 equinox; for the meteorite producing fragment they are given for the 1950.0 equinox.

Object	Date	Corr. geocentric radiant		V_∞	a	e	q	i	ω	Ω	π	Sources
		α [°]	δ [°]	km/s	AU		AU	[°]	[°]	[°]	[°]	
Apophis (99942)	Apr 13	214.2	-30.8	12.5	0.922	0.191	0.746	3.3	126.4	204.4	330.9	[1]
Fragment	1969 Apr 7	212.2	-27.2	11.6	0.926	0.13	0.808	1.7	134.5	197	331.5	No 14 [2]

Sources: [1] – Shor (2009), http://www.ssd.jpl.nasa.gov/, [2] – Terentjeva (1989).

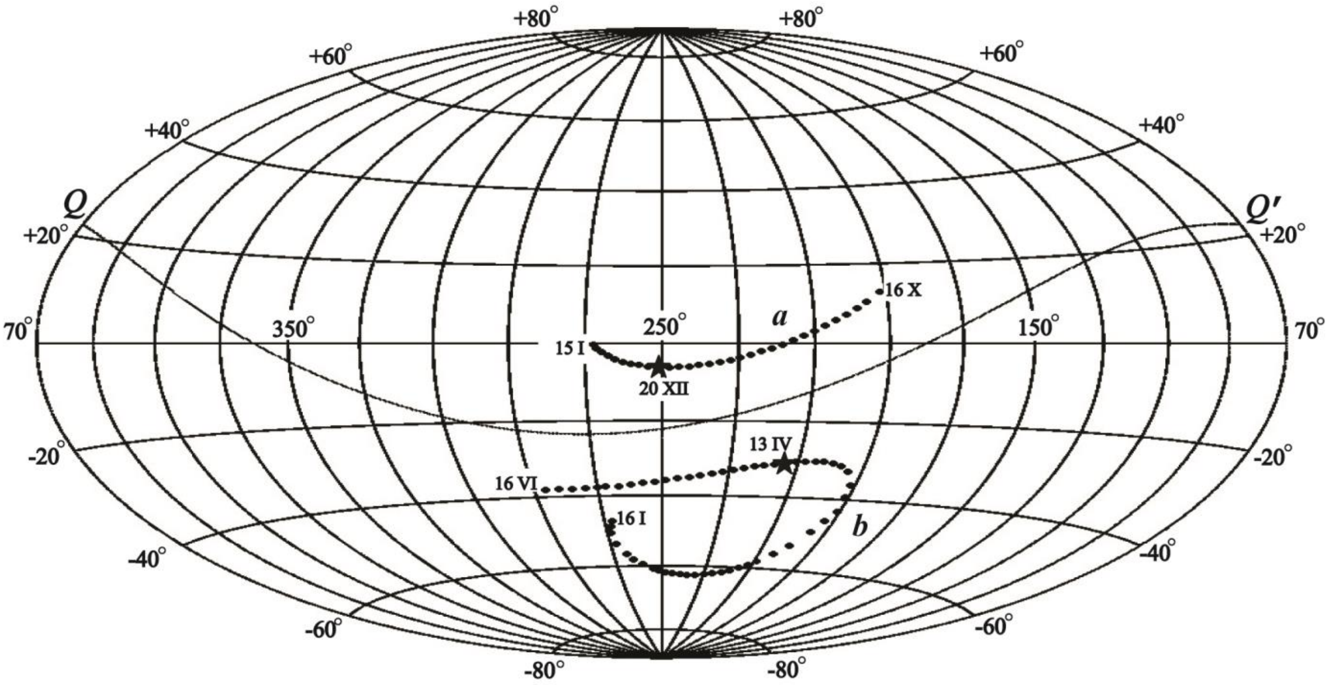

Figure 1 – Ephemerides of the theoretical geocentric radiant of asteroid Apophis (*a* – in the area of the descending node, *b* – in the area of the orbit’s ascending node). An asterisk marks radiants for the moment of appulse. *QQ'* – ecliptic.

During three months, Apophis' geocentric radiant moves along the curve *a* (*Figure 1*), located northward from the ecliptic and corresponding to the appulse area in the region of the orbit's descending node, but further within a short period of time, the radiant is redeployed southward from the ecliptic, and during five months moves along the folded line *b*, corresponding to the appulse area in the region of the orbit's ascending node.

Table 1, provided herein, shows that the meteorite producing object was observed 6 days before the Apophis' passing the appulse of April 13 in the region of its orbit's ascending node.

On the basis of the above, it can be concluded:

1) the discovered meteorite producing body could be a fragment of the asteroid Apophis or they both could have a common origin;
2) it is reasonable to observe large meteor bodies (in the appulse area – April 13), which can be found on the Apophis' orbit or nearby.

The more detailed research will be published in the *Journal of the IMO (WGN)*.

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