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**POSSIBLE COLLISIONS OF ASTEROIDS WITH THE EARTH**

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**ABSTRACT**

With regards to the risk of global catastrophe, it is necessary to determine all possible collisions of hazardous asteroids with the Earth in good time despite low probability of collisions, and explore the corresponding trajectories. The structure of initial conditions, corresponding to possible collisions, may be very complicated; due to resonant returns it is similar to fractal structure.

We discuss the case of asteroid 2015 RN35 and Apophis. The method of approaches and collisions detection includes initial conditions variation using Everhart integrator and ephemerides DE430, as well as DE405. The calculations are performed using a computer cluster of the Saint-Petersburg State University.

Important characteristics of investigated trajectories, including relative positions and sizes of keyholes, leading to collisions, are stable under small changes of motion model. Now more than  $10^2$  collisions of Apophis with the Earth are possible. We have investigate time dependence of Apophis keyholes positions, and free of the keyholes regions of initial conditions. It is possible to move Apophis in any region without collisions, using impact between 2022 and 2029; the impactor mass less than  $10^3$  kg is sufficient.

We have detected more than 10 possible collisions of Apophis with the Moon, first in April 2056. It has largest size of the keyhole; the keyhole located very close to the keyholes, corresponding to collisions of Apophis with the Earth in 2055, 2060, 2056. Rough estimations of collision probabilities are:  $0.5 \cdot 10^{-7}$  (Earth, 2055),  $3 \cdot 10^{-7}$  (Earth, 2056),  $0.06 \cdot 10^{-7}$  (Moon, 2056),  $1 \cdot 10^{-7}$  (Earth, 2060). The next is presented in the <http://neo.jpl.nasa.gov/risk>.

The first stage of observations of asteroid 2015 RN35 until 03.11.2015 corresponds to the JPL solution 30.11.2015. We have derived to 154 possible collisions in XXI century, using this solution. 7 collisions presented in the <http://neo.jpl.nasa.gov/risk> are presented in this list too. The second stage of observations of asteroid 2015 RN35 until 07.03.2016 corresponds to the JPL solution 07.03.2016. We have derived 21 possible collisions in XXI century, using this solution. 7 collisions presented in the <http://neo.jpl.nasa.gov/risk> are presented in this list too. Very interesting is close approach 2015 RN35 to the Earth at October 1962. Minimum geocentric distance is about 0.02 a.u., minimum visible magnitude is about 19. The possibility exist to find old observations, containing 2015 RN35. After approach 2015 RN35 to the Earth on 15.12.2022 (minimum geocentric distance is about 0.0043 a.u.), sizes of keyholes, as well as relative keyholes positions, are multiplied by about 100. The complicated structure of keyholes of hazardous asteroids must be taken into account at the design of collisions eliminating. A closer look at the keyholes is called for.

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