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Keyhole-Distribution

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Abstract:

The recent example of Asteroid (99942) Apophis shows the relevance of keyholes. The trajectory of this asteroid at its encounter in 2029 will be near a keyhole and for many years it was not sure, if it will go through the keyhole, that the trajectory changes into a 7:6-resonance. The consequence of a keyhole swing-by of an asteroid is a hit of the earth after the resonance time. But this primary keyhole is surrounded by smaller secondary keyholes: They are primary keyholes at the next resonance, when the trajectories through primary keyhole hit the planet. Analogical keyholes of the third fourth, fifth , … grade exist, becoming smaller and smaller.

The goal of this paper is to give an overview, where this keyhole sectors will be in the b-plane for asteroids with different characteristics of mass and approaching velocity. But this paper has not the demand to be used for quantitative statements and predictions. A qualitative overview of the keyhole distribution and a support of the understanding of the keyholes is the main intention. For precise keyhole identification it is not available.

The best numeric methods of calculation are not able to include exactly different disturbances, for example Yarkowski-effect and the YORP-effect because of unknown characteristics of the asteroid. This disturbances cause a slowly changing of the orbit parameters, the orbit is not stable, without any swing-by influence. For longer periods this uncertainty increases and prediction is difficult and for periods of centuries often impossible.

The basic idea of this paper is, to understand the swing-by of an asteroid at the earth as a gravity-assist (GA) of a spacecraft at a planet. With the GA a spacecraft takes Δv from the planet and changes in a new trajectory to an other planet - with the GA an asteroid changes his trajectory. If it is a trajectory of resonance the asteroid will hit the earth next time. After this the point of intersection of the trajectory with the b-plane is determinated to designate the keyhole.

To get all keyholes, all orbits of resonance in all planes must be observed and given to this GA-calculation. If there is a ratio of resonance n:m with m for the number of asteroid-years and n for the number of earth-years, the maximum of n (n-max) will be length of time in years which will be observed with respect to an impact. The m are limited by the time limit n-max and by the obtainable trajectories by GA.

All these observed keyhole-orbits are given to the GA-calculation, first to see if they can be reached by GA, and then to determinate their geocentric trajectories. Their intersections with the b-plane create a “map” of keyholes in the b-plane, the goal of

this paper. This “map” shoes the distribution of the keyholes (not their area) in reference of the characteristics of the asteroid, mass and approaching velocity.