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Optimizing a planetary defense shield using asteroids in resonance orbits

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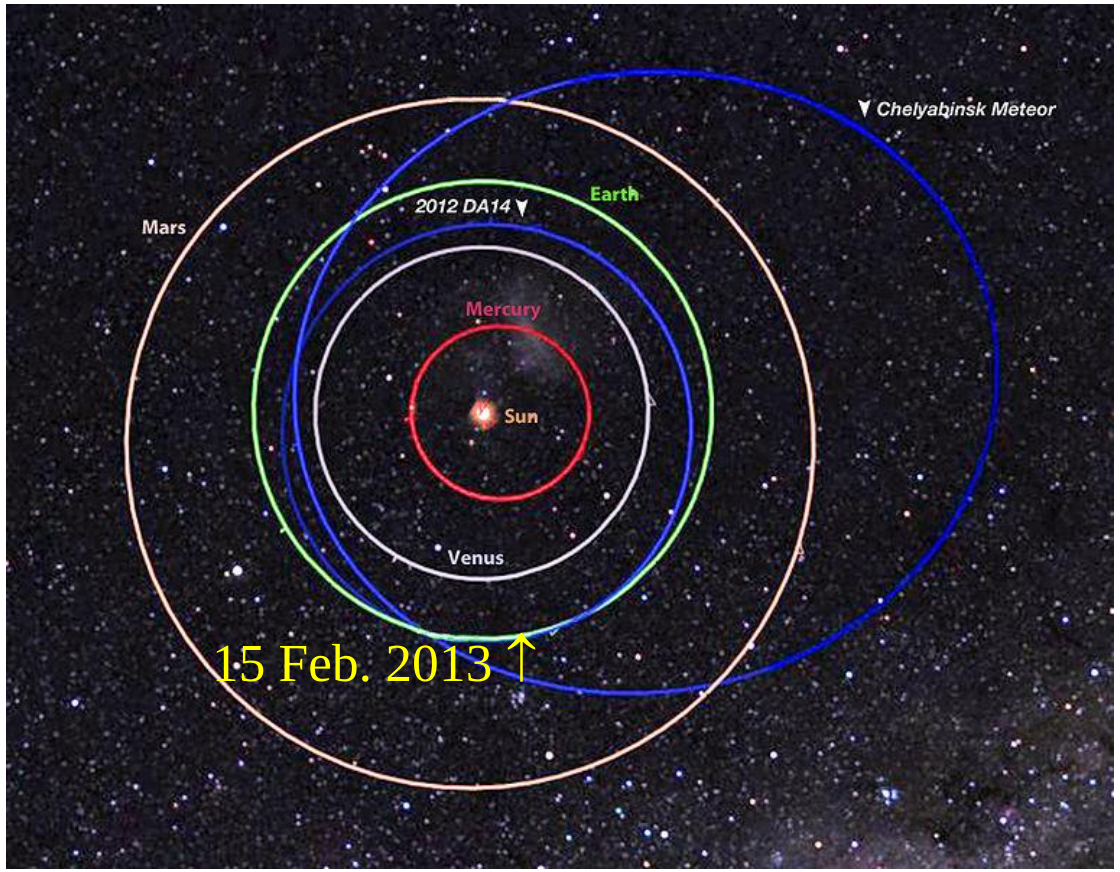
2021 IAA Planetary Defense Conference

The Chicxulub Impact

10km NEA (or 6km comet) hit shore of Yucatan 65 million years ago.
Over 70% of plant and animal species perished from the blast, worldwide wide fires (from impact debris re-entering the atmosphere), and the collapse of photosynthesis in the cold dark years that followed. The dinosaurs died, and now humans rule, because dinosaurs had no space program, no planetary defense.

15 February 2013 – 2 NEA's near Earth



- The Chelybinsk asteroid approached from the Sun, so it was a "bolt out of the blue", we had no warning.
- The larger (50m) NEA was discovered a year ago and flew by Earth at a record (for a non-impacting asteroid) 27,700 km altitude

• Most NEA's are Amor objects like Chelyabinsk, with perihelion inside Earth's orbit and aphelion in the Main Belt. The NEA's velocity relative to Earth is mainly towards the Sun before perihelion and mainly away from it after, so **a rather large fraction** approach from a direction too close to the Sun to be observed from Earth's surface, or from low-Earth orbit.

15 February 2013 –
Russia gets struck again (Chelyabinsk)

- Above, a crater on the ice of Lake Chebarkul caused by a piece from a 20-meter Near Earth Asteroid
- Airburst at ~20 km with about 500 kilotons of TNT equivalent energy -

Concept of using resonant orbit for deflection potentially hazardous objects

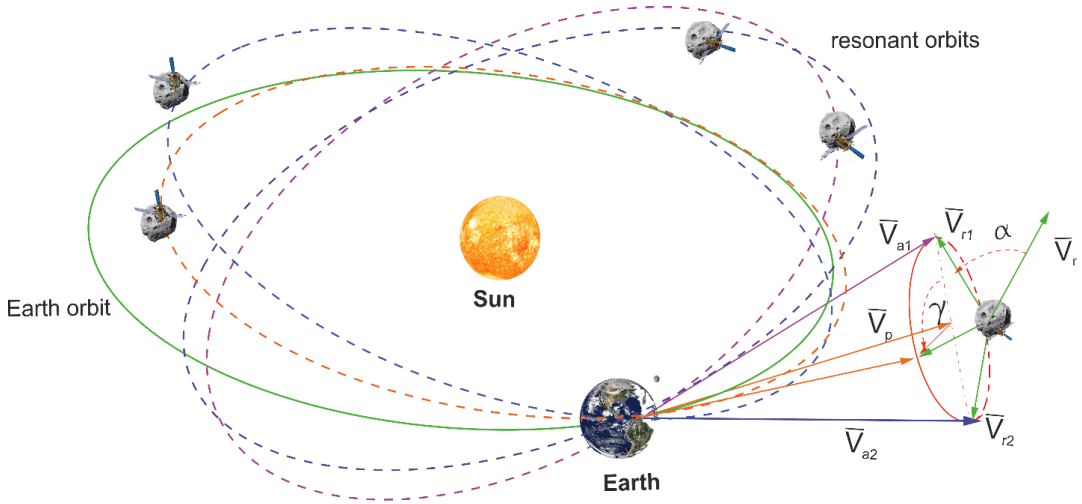


Fig. 1 Transfer projectile asteroid to resonant 1:1 orbit

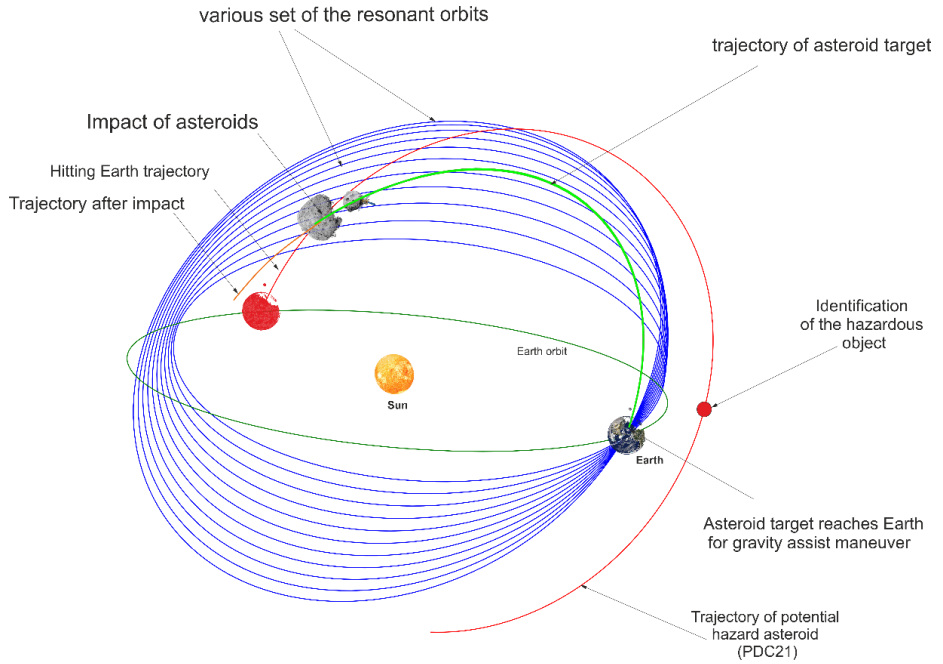


Fig. 2. The concept of using a projectile asteroid to deflect a near-Earth hazardous object

Capture and transfer of asteroid 2012 TC4 to 1:1 1:1 resonant orbit

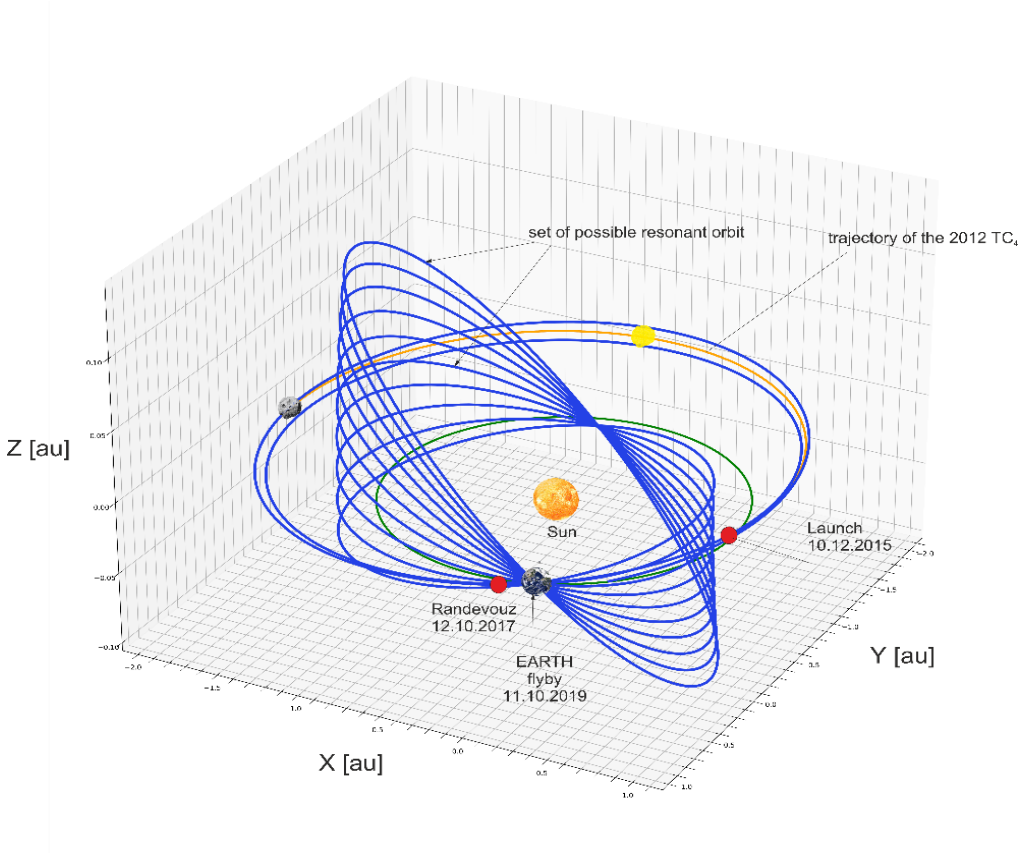


Fig. 3. Trajectory of the flight to the asteroid 2012 TC4 with its subsequent transfer to the resonant 1:1 orbit to the Earth.

Table 1. Parameters of the motion of the spacecraft to 2012 TC4 with a subsequent landing and transfer of the asteroid to a resonant orbit after a gravity assist maneuver near the Earth.

Date of launch/flyby	Celestial body	Height of flyby, 10^3 *km*	Relative velocity value, km/s	ΔV, *km / s*
10.12.2015	Earth	0.2	6.7	5.11
12.10.2017	2012 TC4	-	0.34	0.34
11.11.2017	2012 TC4	-	0	0.17
20.10.2019	Earth	1.1	6.4	0

PDC21 Example

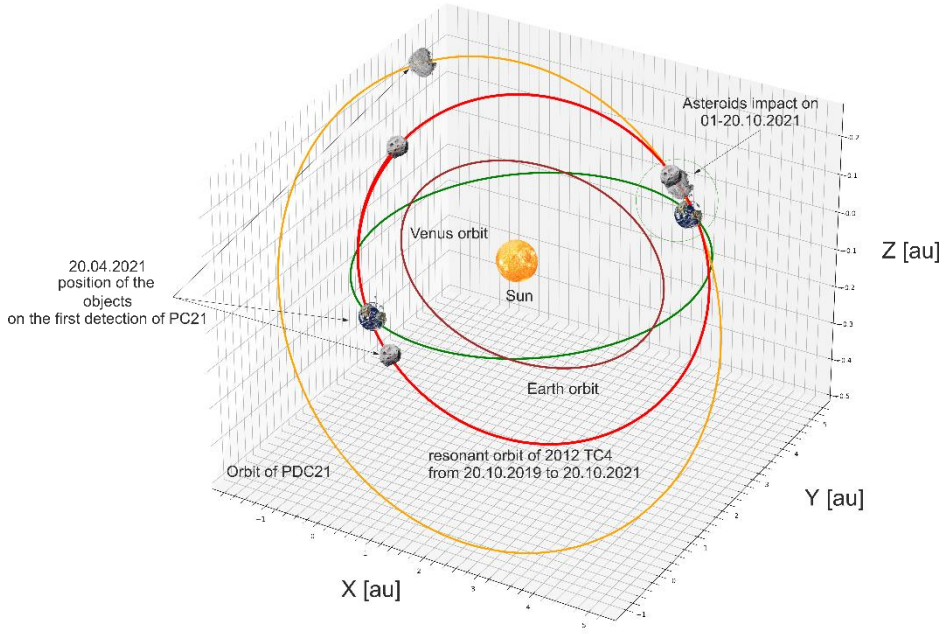


Fig. 4. Trajectory of the projectile asteroid before approaching PDC21 in the heliocentric (J2000) ecliptic coordinate system.

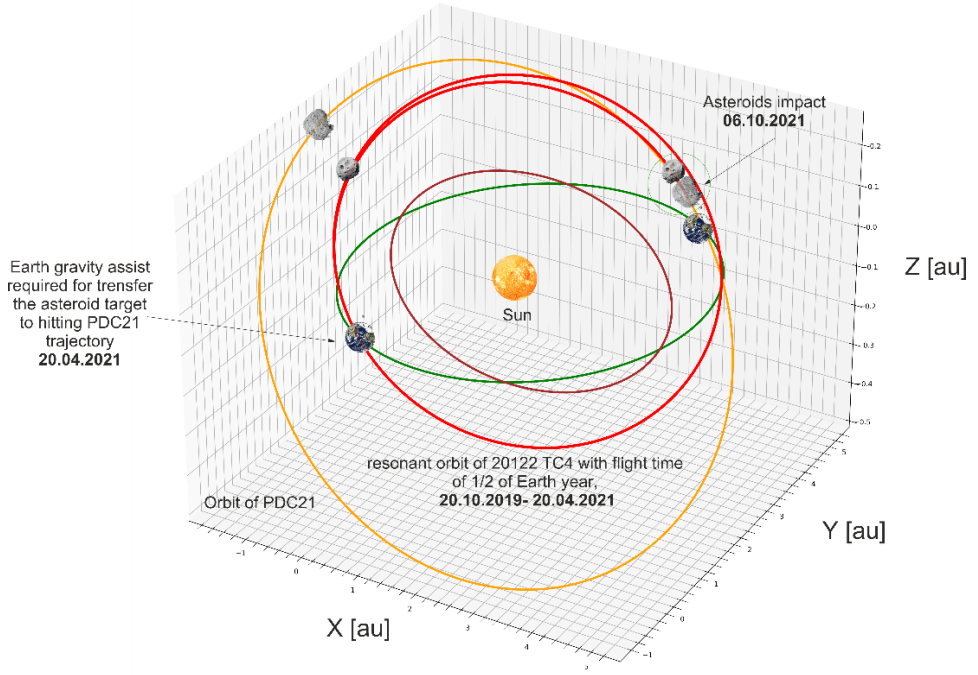


Fig. 5. Trajectory of the projectile asteroid before the collision with PDC21 in the heliocentric (J2000) ecliptic coordinate system.

(99942) Apophis Example

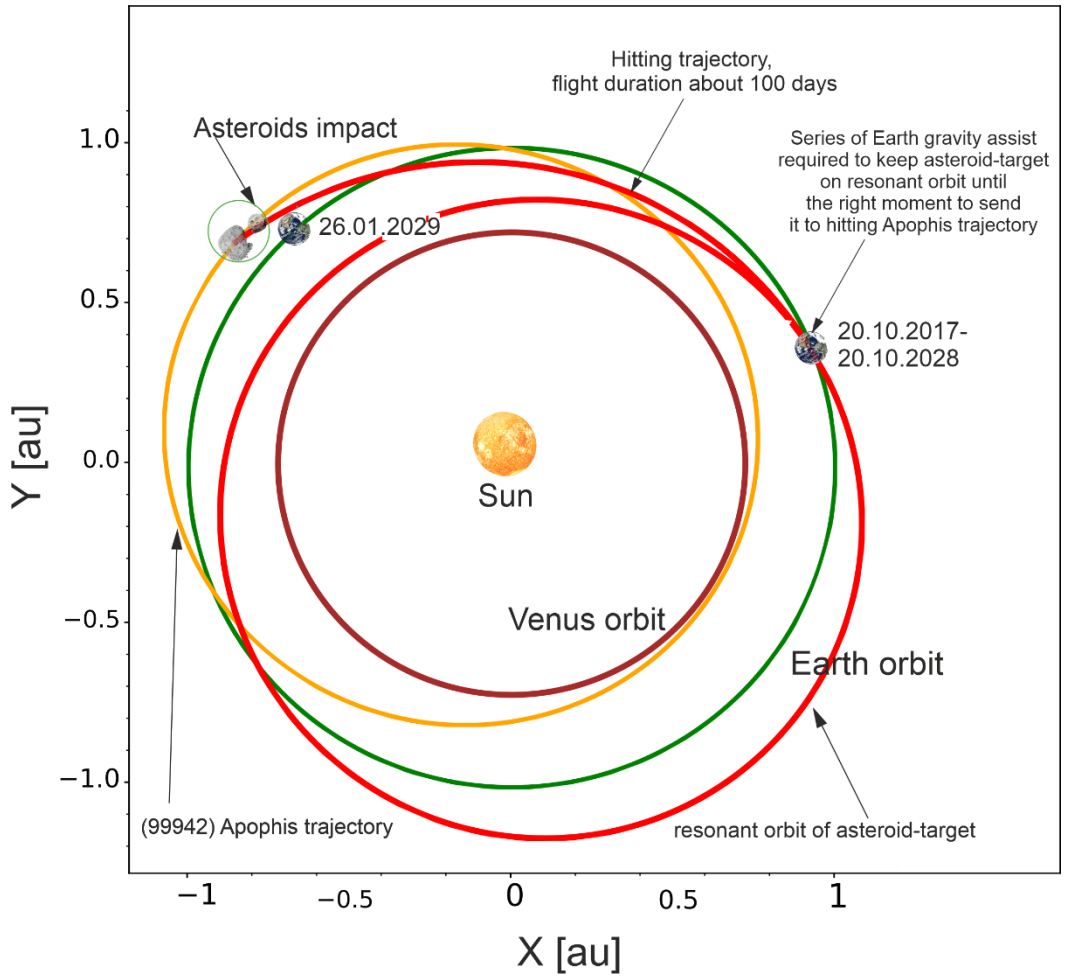


Fig. 6. Trajectory of the projectile asteroid before the collision with Apophis in the heliocentric (J2000) ecliptic coordinate system.

The concept of operations for dangerous asteroids intercepting

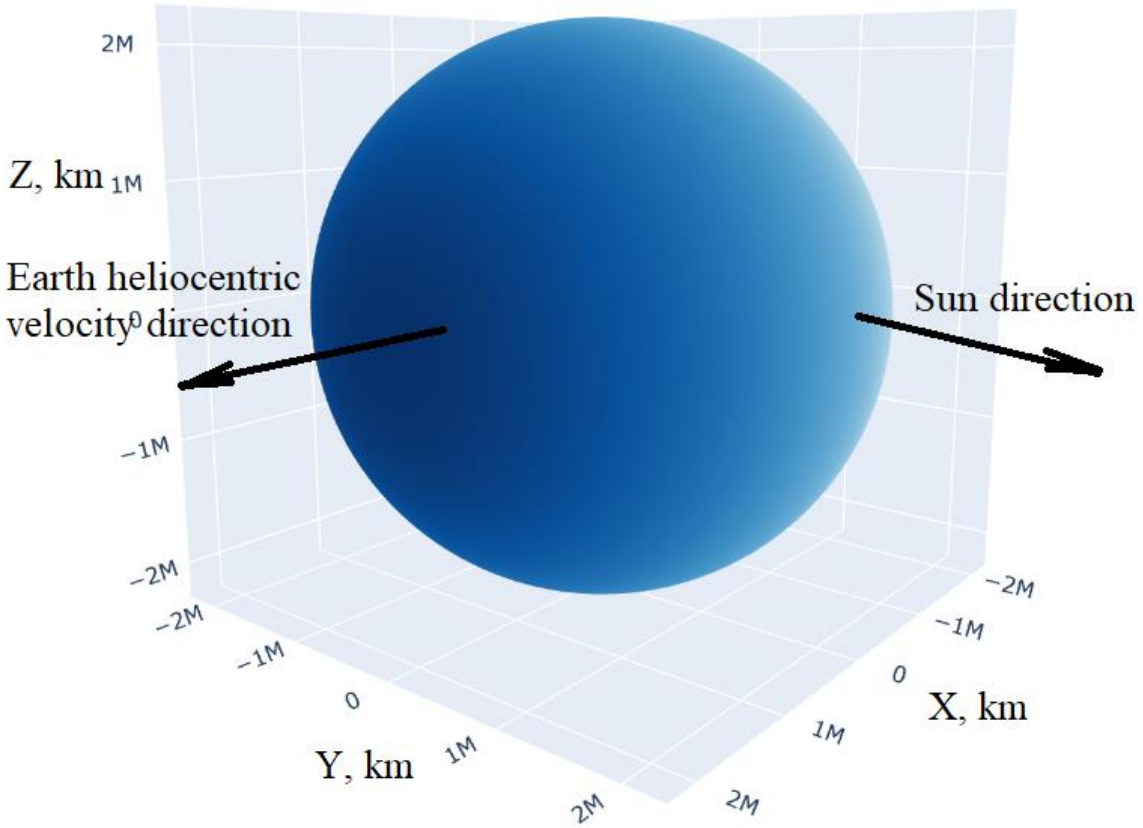


Fig. 7. Sphere after 10 days from Earth gravity assist in Sun-Earth rotating frame

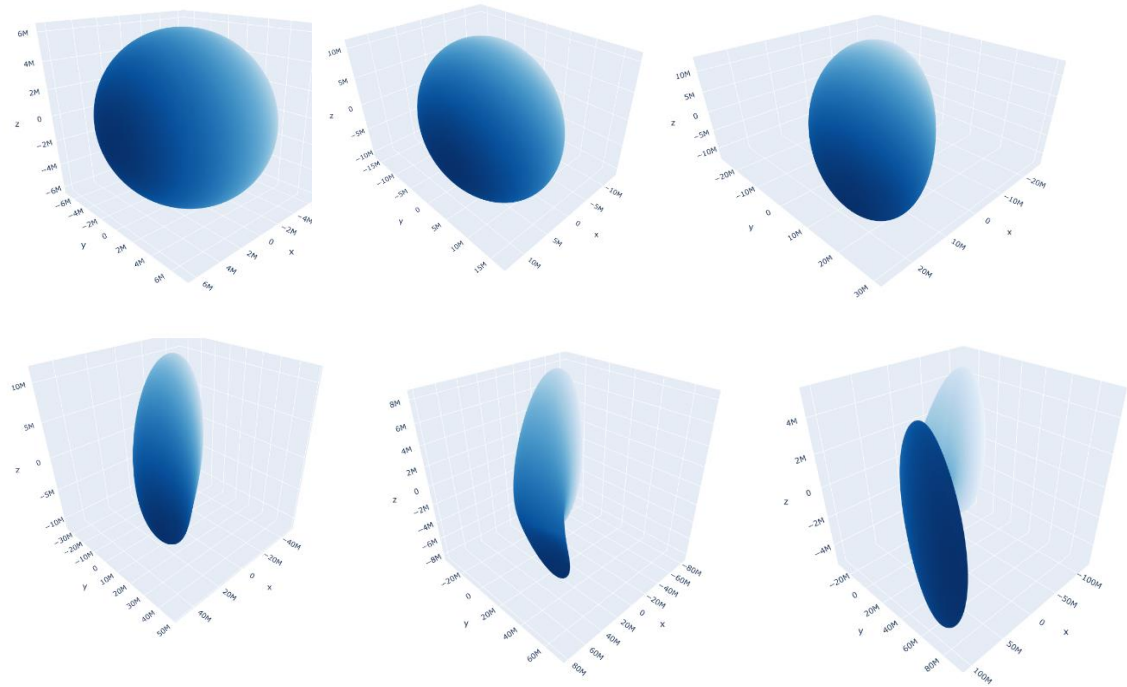


Fig. 8. Deformation of sphere through 1 to 6 month from Earth gravity assist in Sun-Earth rotating frame

The concept of operations for dangerous asteroids intercepting. Example for PDC21 and Apophis cases

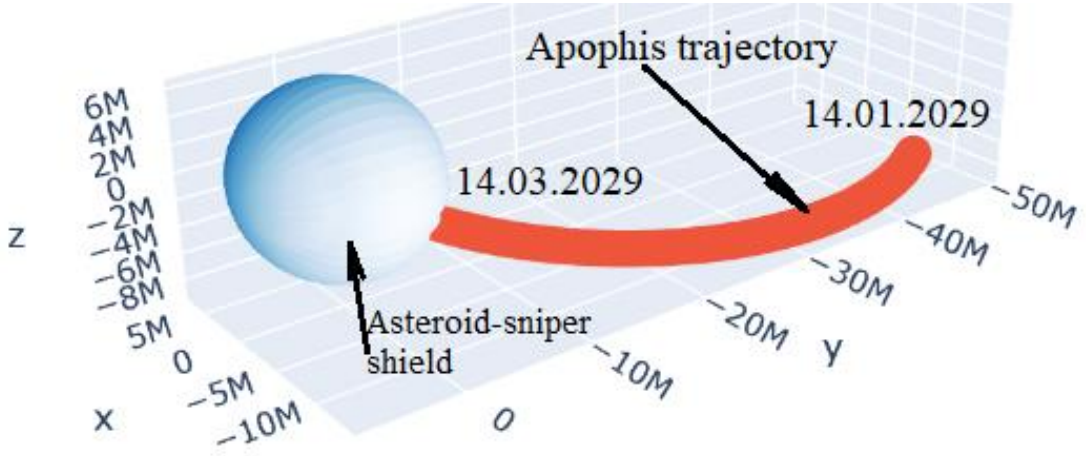


Fig. 9. The trajectory of the virtual asteroid PDC21 from 20.04.2021 to the moment of crossing the sphere on 20.09.2021.

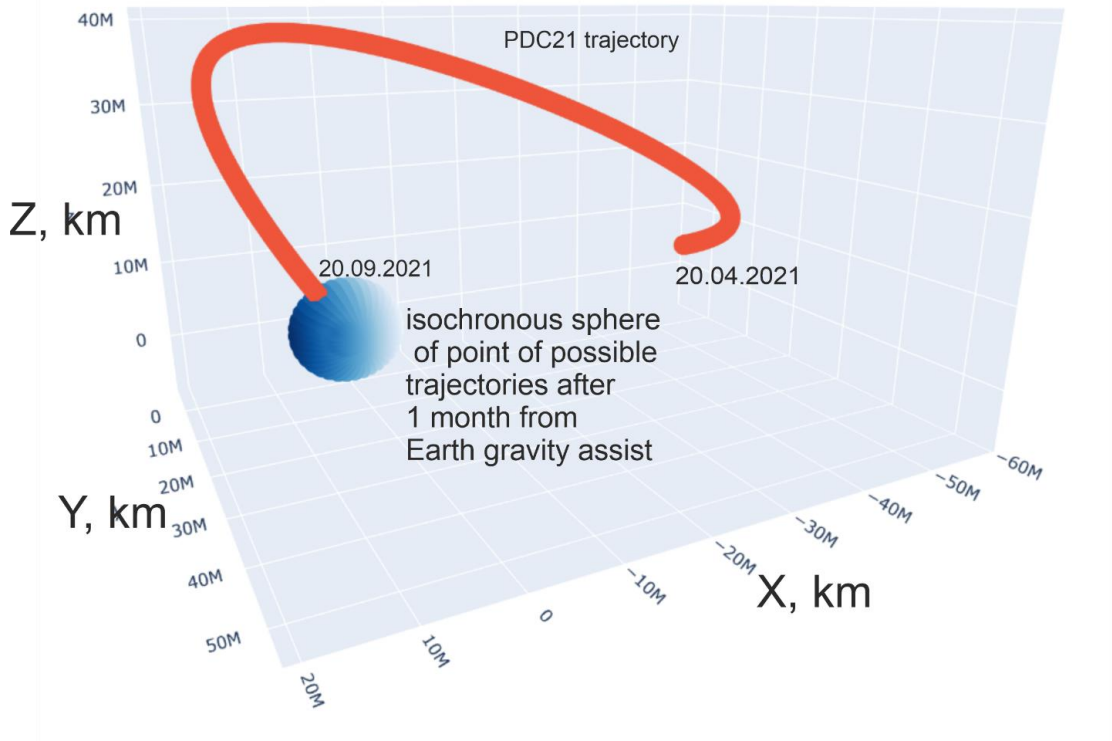


Fig. 10. Trajectory of the virtual asteroid PDC21 from 20.04.2021 to the moment of crossing the sphere on 20.09.2021.

Conclusions

- The research show that the use of resonant orbits can prevent the collision of a potentially dangerous object with the Earth or decrease the possibility of such a collision. The virtual dangerous asteroid PDC21 discovered on April 20, 2021 is considered as a potentially dangerous object. A realistic approach to the asteroid (99942) Apophis is being considered and is expected to occur on April 14, 2029. A virtual asteroid-snipe collision with PDC2021 is assumed to occur on October 20, 2021. Asteroid 2012 TC4 is assumed to be sniper.

- The results of the calculations given in this paper have shown that the deflection of a dangerous object is possible if a dangerous asteroid is detected at least six months before the expected collision with the Earth. In the case of detection of the asteroid for a long time before the possible dangerous approach (for example, the detection of Apophis), the possibility of its deflection significantly expands, as well as expands the number of available asteroids, which in this case can be used as an asteroid projectile.

- It is proposed to use a one asteroid on resonant orbit to form a shield that could prevent an asteroid impact. The preliminary calculations for ideal case when the asteroid-sniper is random and has a relative velocity near Earth about 3.5 km/s, shows that such assumption allows to provide a full protection of the Earth by building a shell consisted of trajectories received by Earth gravity assist.

Thanks for Your Attention !
Any questions ?

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Dunham, Eismont, et al., "Using Small Asteroids to Deflect Larger Dangerous Asteroids", AIAA Paper GNC13-1663359, presented at GNC conference, Boston, Mass., August 2013
Ledkov, Dunham, Eismont, et al., "Near Earth Asteroids Transfer onto Earth Resonance Orbits with the Use of Gravity Assist Maneuvers", presented at 24th ISSFD, Laurel, MD, USA, May 6, 2014

A .pdf version of these slides is available upon request