CHANGING THE SPIN OF AN ASTEROID – A KINETIC-IMPACTOR TEST MISSION. L. Drube[1], A. W. Harris[1] and S. Schwartz[2], [1]Institute of Planetary Research, German Aerospace Center (line.drube@dlr.de), [2]Nice Observatory.

Introduction: We present a concept for a kinetic impactor demonstration mission that aims to change the spin rate of an asteroid rather than the orbit of the asteroid around the Sun or, for example, the orbital motion of a moon around its primary. Similar information to the aforementioned existing concepts could be obtained by measuring the change in the spin period of an asteroid resulting from an impact that transfers significant angular momentum to the asteroid, i.e. a large value of m_i v_i d sinθ (see Figure 1).

The mission can be either a mission with an impactor and an observer spacecraft, or one with only an impactor, where the change in the spin period will be measured from Earth-based telescopes.

Estimation of the effect: A simple estimate of the magnitude of the possible change in rotation period with such a mission can be calculated by using the following angular momentum conservation formula:

$$I_Z \omega_{Z0} + m_i v_i d \sin\theta = I_Z \omega_Z + L_\beta + L_{lost}$$

where Z is the rotation axis of the asteroid, I_Z the asteroid's moment of inertia, i denotes the impactor, and β the ejecta. For the rest see Figure 1.

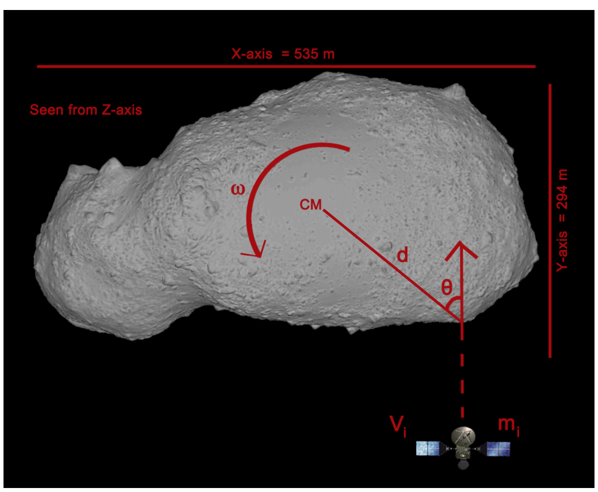

Figure 1. Illustration of a kinetic impactor changing the rotation period of an asteroid. *Credit: Robert Gaskell produced the shape model of Itokawa's north side used here [1].*

Using Itokawa as an example we assume the following: no ejecta (thus underestimating the efficiency); no angular momentum lost in other processes (thus overestimating the efficiency); impactor mass = 500 kg; relative velocity = 10 km/s; the distance d*sinθ = 250m; Itokawa's moment of inertia around the rotation axis = 7.7686*10^8 km^2kg and its rotation rate = 12.132 hr [2]. It follows that the angular velocity after the impact will be:

$$\omega_Z = \frac{500kg*10km\ s^{-1}*0.25\ km}{7.7686*10^8 km^2 kg} + 1.4386*10^{-4}\ s^{-1}$$

Which is a change of about 8 minutes from the original rotation rate. This magnitude of change in rotation rate will be visible even from Earth-based observatories in the case of Itokawa.

Detailed computer modeling of the impact is in progress.

Asteroid target shape: An elongated asteroid would be preferred, because it has a relatively low mass compared to the possible impact distance from the center of mass, and if impacted at the right time, it might be possible to increase the amount of ejecta in the direction close to the opposite of the direction of angular velocity change, thereby maximizing the momentum enhancement factor β. A pronounced shape will also make it easier to measure the rotation rate from Earth-based telescopes.

However, more regularly shaped asteroids are not excluded for use as targets, provided the change in rotation rate is visible from the observer spacecraft for a two-spacecraft mission, or visible from Earth in the years following the impact for a one-spacecraft mission.

One-spacecraft mission: The best demonstration mission would be a two-spacecraft one, in which a second spacecraft observes the impact itself, the crater formation, the ejecta, and the exposed surface in the crater.

If however the budget only allows for one spacecraft, then this would normally reduce the science greatly, as there would only be very limited knowledge about the properties of the asteroid relevant to understanding the results of the test impact. However if the target asteroid were one that had been observed previously with spacecraft, then the lack of an observer spacecraft would not necessarily be a serious drawback. The most likely candidates to be used as targets are Itokawa (Hayabusa I mission target), Bennu (Osiris-Rex mission target) and 1999 JU3 (Hayabusa II mission target). Mission analyses have however yet to be performed.

In the case of Itokawa the apparent visual magnitude as seen from Earth brightens to between 20-19 every 4 years, with a very close flyby in 2033 [3]. In 2033 the apparent magnitude will be around 16, and it will also be possible to observe it with the Goldstone and the Arecibo radar telescopes (SNR 22 for Goldstone and SNR 310 for Arecibo [4]), whereby any large surfaces changes as a result of the impact might be visible.

The change in the rotation rate due to the YORP effect is so small that it is negligible compared to the effect from the impactor. For example, in the case of Itokawa the YORP effect causes about 0.0072 minutes decrease in the period per year [5], which is 3 orders of magnitudes less than that expected from the concept described here.

Much science can be obtained from observing the impact itself and the ejecta produced. Therefore, in the case of a single spacecraft mission, it would be beneficial to separate the impactor into two parts, such that an imager with data transmission capability could be ejected to fly by the asteroid and observe the impact and the ejecta cloud.

Conclusion: Preliminary studies show that a mission concept in which an impactor produces a change in the spin rate of an asteroid could provide valuable information for the assessment of the viability of the kinetic-impactor asteroid deflection concept. However further studies are necessary to evaluate in detail relevant aspects of the concept, especially the effects of regolith and subsurface structure.

References: [1] Gaskell et al. (2006), *AAS/AIAA Astrodynamics Specialists Conf.,* AIAA paper 2006_6660, Keystone, CO, Aug, 2006. [2] Scheeres et al. (2007) The effect of YORP on Itokawa, *Icarus,* 188, 425-429. [3] *JPL's Horizons web-interface* (Aug 2014) http://ssd.jpl.nasa.gov/horizons.cgi#top [4] *Near-Earth Object Human Space Flight Accessible Target Study (NHATS) website* (Aug 2014) http://neo.jpl.nasa.gov/cgi-bin/nhats. [5] Scheeres et al. (2007) The effect of YORP on Itokawa, *Icarus,* 188, 425-429.

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