YORP Effect on Asteroid Ryugu

*Masanori Kanamaru[1], Sho Sasaki[1], Tomokatsu Morota[2], Yuichiro Cho[2], Naru Hirata[3], Naoyuki Hirata[4], Hiroki Senshu[5], Yuri Shimaki[6], Satoshi Tanaka[6], Tatsuaki Okada[6], Tomohiro Usui[6], Seiji Sugita[2], Sei-ichiro WATANABE[7]

1. Osaka University, 2. The University of Tokyo, 3. The University of Aizu, 4. Kobe University, 5. Chiba Institute of Technology, 6. ISAS/JAXA, 7. Nagoya University

The Yarkovsky and YORP effects are recoil force induced by thermal radiation from a surface of an asteroid, which secularly alter the orbit and the spin state of the body, respectively. The combined effect of Yarkovsky and YORP is a key to shed light on the dynamical evolution of asteroid 162173 Ryugu such as the orbital migration from the main belt to a near-Earth orbit and the formation mechanism of the spinning top shape. In this presentation, we aim to investigate the spin-down process of Ryugu from the fast rotation in the past to the current mild spin and compare its time scale with the surface age of the asteroid estimated from the crater statistics.

We conducted a numerical simulation of the YORP effect on asteroid Ryugu based on the orbit, the spin state and the 3-dimensional shape as revealed by Hayabusa2. Given a polyhedral shape model of 49,152 surface facets constructed by the stereo-photoclinometry (SPC), we computed the net torque on Ryugu to change the rotation period and the spin pole direction. As a result, Ryugu is currently decreasing the spin rate (spinning down) in the so-called YORP time scale of 1.2 million years. On the other hand, the obliquity of Ryugu, that is, the tilt angle of the spin pole is increasing toward the obliquity of 180 degrees. The attached figure shows the obliquity dependence of the YORP effect on Ryugu. The solid and dashed curves represent the rate of change of the obliquity and the spin rate of Ryugu. Note that the obliquity curve has the asymptotic nodes where the spin pole becomes stabilized at 0, 90 and 180 degrees. For Ryugu, there are thresholds around the obliquity of 36 and 144 degrees which determine the subsequent evolution of the spin state. The vertical dotted line at the obliquity of 172 degrees denotes the current value of Ryugu, where the spin rate is decreasing and the spin pole approaches an obliquity perpendicular to the orbital plane.

Moreover, we surveyed various initial spin states and confirmed that only limited combinations of the initial period and obliquity could reach the current spin state of Ryugu. The time scale of the spin evolution was at most 2.3 million years, which is shorter than the surface age of approximately 9 million years (Sugita et al., 2019). This study indicates that Ryugu experienced a disturbance of the spin state such as impact cratering or an Earth flyby at least in this few million years.

Keywords: Asteroid, Ryugu, YORP effect

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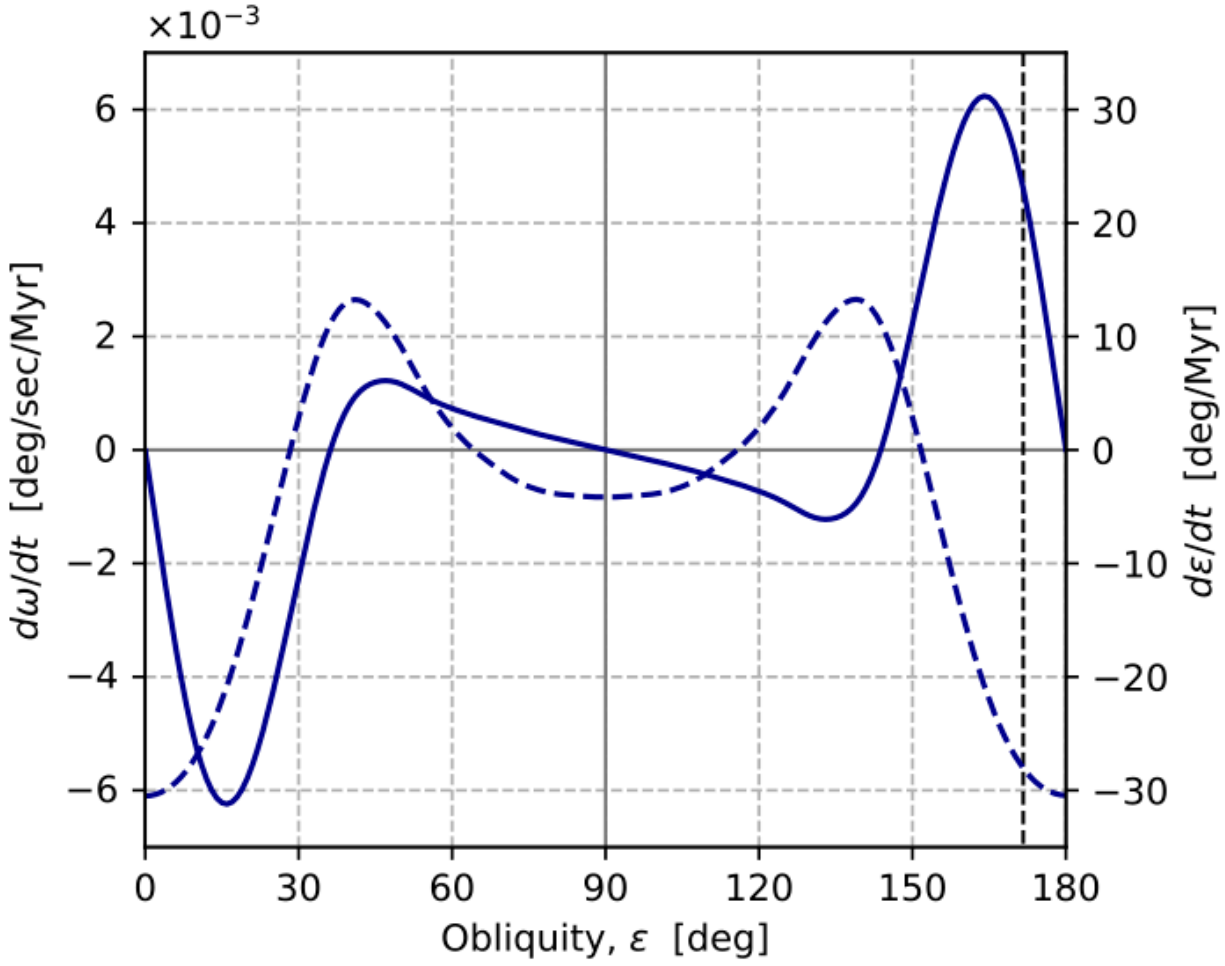

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