Yarkovsky-Driven Orbital Migration of Asteroid Ryugu: Implications for its Collisional History and Source Family

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With the ongoing analysis of samples brought back from the asteroid Ryugu, there is a growing need to understand their geological/dynamical context. It is essential to identify the asteroid family from which the asteroid Ryugu originated and to clarify the orbital evolution path from the main belt to the near-Earth region.

In this study, we estimate the time scale of Ryugu's orbital evolution in the inner main belt based on a thermophysical simulation. We simulated the temperature distribution on the surface of Ryugu over an orbit cycle using the current orbit, spin, and thermophysical properties (Watanabe et al. 2019; Okada et al. 2020), and calculated secular change in semi-major axis that induced by anisotropic thermal radiation, i.e., the Yarkovsky effect. A Yarkovsky drift rate was obtained by scaling that for the near-Earth orbit to the inner main belt. The thermophysical simulation was performed by a dynamical simulator for asteroids, Astrohsaper (Kanamaru et al. 2021).

As a result, it was estimated that Ryugu will take approximately 700 million years to migrate through the inner main belt from 2.1 to 2.5 au. The right panel of Figure 1 shows the time scales for Ryugu to reach the ν_6 resonance by Yarkovsky as a function of initial orbital elements. ν_6 is the secular resonance with Saturn and one of the most powerful resonances as an escape hatch to provide near-Earth asteroids.

In this region, there are two asteroid families that are possible candidates for the origin of Ryugu: Eulalia and New Polana as shown in the left panel of Figure 1. The formation ages of these families are estimated as ~830 million years and ~1.4 billion years, respectively (Bottke et al. 2015). The Yarkovsky time scale estimated in this study is comparable with the formation age of Eulalia family, while it is shorter than that of New Polana family. If Ryugu originated from Eulalia family, Ryugu was formed at the same time with the family formation and was transported to the ν_6 resonance. On the other hand, if Ryugu originated from New Polana, a parent body of Ryugu was formed during the family formation. It is likely that Ryugu is a rubble pile of the second- or later generation that experienced multiple times of catastrophic disruption. Because the Yarkovsky drift is less effective for a massive body, Ryugu would have spent several hundred million years as the larger parent body.

In the future, we will attempt to shed light on the evolutionary history of Ryugu by comparing the results of analysis of returned samples.

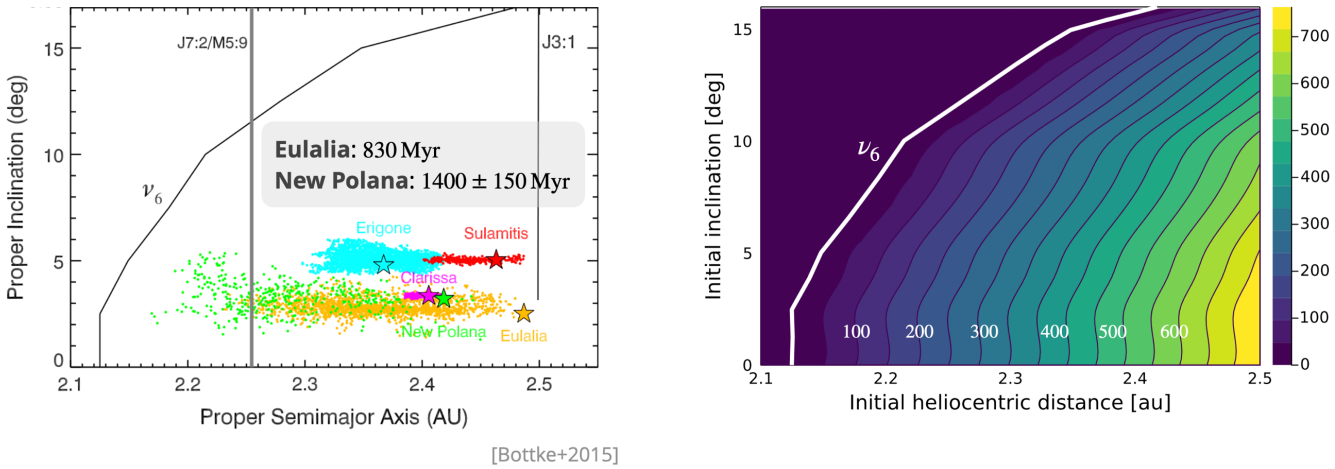

Figure 1. Potential source family of asteroid Ryugu and time scales to reach ν_6 resonance.

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