Assessing Martian moon precursors' impact probability: Implications for moon formation frequency and water supply to Mars

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The reflectance spectra of the Martian moons Phobos and Deimos similar to those of carbonaceous asteroids support the planetesimal capture theory for their origin (e.g. Rivkin, 2002). The drag-capture theory (Hunten, 1979; Sasaki, 1990) proposes gas drag from the primordial Martian atmosphere, formed by trapping solar nebula gas, as an energy dissipation mechanism for capture. This theory suggests that the moons are survivors of planetesimals that accreted to Mars, potentially transporting water to terrestrial planets due to their carbonaceous composition.

A significant challenge to the capture theory is its apparent inability to explain the moons' small orbital inclinations of less than 2 degrees. However, our previous study (Matsuoka & Kuramoto, 2023, JpGU) demonstrated that the formation of low-inclination moons is inevitable in such capture processes by considering capture via temporary capture. Combining the capture probability of temporarily captured bodies obtained in our previous study with the fraction of planetesimals temporarily captured during their crossing of the Martian Hill sphere obtained by Higuchi & Ida (2017), we obtain a lower limit for the capture rate per Martian mass increment, indicating that this type of capture is not rare.

This capture rate per Martian mass increment provides insights into the frequency of Martian moon formation, the water supply rate to Mars and the circum-Mars environment during the accretion period. However, the actual value relative to this lower limit is varies largely on the impact probability of Hill-sphere-crossing planetesimals on Mars. In this study, we performed the Sun-Mars-planetesimal circular restricted three-body problem including gas drag from the solar nebula and the proto-atmosphere, to estimate the impact probability of these planetesimals on Mars. Our discussion in this talk focuses on the constraints imposed by these results on the frequency of Martian moon formation and associated water supply rates.

Keywords: Martian moons, Planetary accretion, Capture theory