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Tidal Dynamics and Rotational States of TRAPPIST-1 Planets: Implications for Observations

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Recent JWST observations of the thermal emission from TRAPPIST-1 b and c have provided new constraints on their possible atmospheres (Greene et al. 2023; Ih et al. 2023; Zieba et al. 2023; Lincowski et al. 2023). In this context, accurately modeling their rotational states and tidal heating is essential for interpreting these observations. A widely accepted assumption is that the TRAPPIST-1 planets have reached a synchronous rotational state due to tidal evolution. However, our simulations indicate that planet-planet interactions prevent exact synchronization with their orbital motion. These interactions induce sub-stellar point drifts that lead planets to experience day-night cycles, with solar day lengths ranging from 43 to 656 years, depending on the planet. Tidal dissipation within a plane can significantly impact its thermal state, as observed in Io, the Solar System's most volcanically active body (Renaud et al. 2018; Kervazo et al. 2021). Recent constraints on the nightside brightness temperatures of TRAPPIST-1 b provide upper limits on the tidal heat flux, offering insights into the planet's rotational state and obliquity for a given internal structure (Ducrot et al., in revision). Additionally, different internal structures lead to varying dissipation rates, which can produce measurable effects on Transit Timing Variations (TTVs). These variations may serve as a key observational tool to distinguish between different internal compositions and dissipative properties of the TRAPPIST-1 planets.

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