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NATURAL DYNAMICAL PROCESSES ON FAST ROTATING ASTEROIDS

Abstract

Asteroids are relics from the formation of the solar system. Due to the fact that asteroids do not have active geological processes acting on them, their structures are thought to be static since their formation. However, in recent years, evidence of dynamical processes that asteroids undergo has been found. The existence of the Yarkovsky and YORP effects provide a continuous perturbing mechanism for the asteroids' orbital and spin states. While these effects are much smaller than sporadic collisions or close planetary flybys, they are constantly acting over millennia, leading to large changes in asteroid states. Binary and contact binary asteroid systems, which constitute about 20 percent of the near-Earth asteroid population, are proof that such effects become significant over time since they are likely formed from rotational fission driven by YORP. In past research, asteroids have been modeled as an aggregation of masses, known as a mascon model, which uses N-body dynamics to investigate the evolution of small bodies. This paper investigates the dynamics that shape and reshape asteroids with a new approach. Using rigid body dynamics and modeling the asteroid and boulders on its surface as polyhedra, a simulation tool was built to examine the changes an asteroid undergoes at high spin rates. Specifically, this tool allows us to observe the changing balance between the gravitational pull and rotational acceleration on asteroid surfaces. The tool propagates asteroids at angular velocities around their fission condition and in different tumbling states, and then maps where the surface and boulders are not stable. This instability is measured using surface accelerations and gravitational slopes. Unstable boulders are propagated to launch off the asteroid or roll on its surface, depending on the excess momentum they have. This leads to ejection from the system, orbit insertion around the asteroid, or return to crash back into the asteroid. Surface areas with high slopes are reshaped to new equilibria. The effects on the asteroid's rigid body parameters and state as a whole are observed as well, and the change in its rotation state is monitored. The asteroid's redistribution of mass is accounted for as the asteroid rotates and the momentum transfer between asteroid and boulders is integrated into the propagation. By exploring the changes that high spin rates induce we demonstrate the processes that lead asteroids to equilibrium states observed regularly and provide a better understanding of the topology we can expect to find on asteroid surfaces.