MINIMUM ENERGY CATASTROPHIC DISRUPTIONS

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Dramatic alteration of an asteroid's morphology need not involve high energy impacts between bodies. Simple sunlight shining on an asteroid can, through the YORP effect, cause it to undergo dramatic reconfigurations, fission into a binary asteroid or, in some cases, even undergo a catastrophic disruption with the asteroid losing up to 20% of its initial mass. The YORP effect has recently been detected and verified [2,3,6], and thus is relevant to study for its effect on asteroid morphology.

In [4], the effect of YORP torques on the asteroid Itokawa is examined in detail. We find that the body is currently undergoing a deceleration in its rotation rate, implying that it was spinning faster in the past. Extrapolating back on the order of 200,000 years we find that Itokawa should have been spinning fast enough for the distinctive "head" and "body" portions of the asteroid to be in orbit about each other. A study of the orbit that would ensue shows that the system would have been highly unstable, but unable to escape. The two portions would most likely have reimpacted, potentially supplying the seismic energy that has evidently reshaped this asteroid [1].

This analysis has been generalized to explore the energetic stability of contact binary asteroids over a wide range of possible shapes and mass distributions [5]. Although simple models are used, we find profound results that can directly shape our understanding of the current NEA asteroid population, and which provides a link between the YORP effect and rotation rate distributions, the presence of contact binary asteroids, and the creation of orbital binary asteroids. As the angular momentum of a contact binary asteroid changes, we find a series of thresholds at which the minimum energy configuration of the asteroid can change drastically. If a body passes such a threshold it is susceptible to undergoing a large change in its morphology given a relatively modest input of energy. If the body's angular momentum continues to increase, a contact binary asteroid will fission directly into a relative equilibrium orbit configuration. Depending on the shape and mass distribution between the components, the system can either be stable and lead to a binary asteroid system, be unstable but bounded, preserving its contact binary structure, or be unstable and unbounded, leading to escape between the two components. For this last case, the energy of the initial contact binary asteroid has been increased to the minimum value possible that leads to such a disruption of the system.

References

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