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# On the post-impact spin state of the secondary component of the Didymos-Dimorphos binary asteroid system

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NASA’s Double Asteroid Redirection Test (DART) is designed to be the first demonstration of a kinetic impactor for planetary defense against a small body impact hazard. The target is the smaller component of the Didymos-Dimorphos binary asteroid system. The DART impact will abruptly change the relative velocity of the secondary (Dimorphos), increasing the binary eccentricity and exciting librations in the secondary. The observed change in the binary orbit period will be used to infer the “beta factor”, or the momentum transfer efficiency, an important parameter used in planetary defense. The post-impact spin and librational dynamics are expected to be highly dependent on the momentum transferred to the target (i.e., beta) and the shape of the secondary, which is still unconstrained.

In this work, we explore the possible post-impact spin state of Dimorphos, as a function of its shape and beta, assuming it has an ellipsoidal shape and that both bodies have a uniform density. We have conducted attitude dynamics simulations with a modified 3-D spin-orbit model, accounting for the secondary’s shape and the primary’s oblateness, to understand the underlying dynamical structure of the system. In addition, we have used the radar-derived polyhedral shape model of Didymos in high-fidelity Full Rigid Two-Body Problem (FR2BP) simulations to capture the fully three-dimensional nature of the problem. We consider the outcomes from a simplified planar impact, where the DART momentum is transferred within the binary orbit plane, opposite the motion of Dimorphos, in addition to a more realistic case that accounts for the full DART velocity vector (which contains out-of-plane components).

With both simulation tools, we produce the expected signatures of the 1:1 and 2:1 secondary resonances between the free and forced libration periods, corresponding to axial ratios of a/b = 1.414 and a/b = 1.087, respectively. For moderate values of beta (~3), we find that the libration amplitude can exceed ~40 degrees in most cases. For some possible axial ratios, it is even possible to achieve a libration amplitude exceeding 40 degrees with beta values as low as 1. In addition, both codes reveal that the secondary may be attitude unstable in many cases, and can enter a chaotic tumbling state for larger values of beta (~5). In some cases, Dimorphos is able to break from its assumed 1:1 spin-orbit resonance.

In the case with a more realistic impact geometry (where some momentum is transferred out-of-plane), the results are relatively similar. The most noticeable difference is in the cases that result in a chaotic tumbling state. In those cases, the characteristic timescale for entering the chaotic tumbling state is much shorter – typically only several orbit periods are required. We also discuss the feasibility of detecting the post-impact spin state of Dimorphos with ground-based observations.

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