THE POST-IMPACT SPIN STATE OF DIMORPHOS RESULTING FROM THE DART IMPACT. H. F. Agrusa[1,2], I. Gkolias[3], K. Tsiganis[3], A. J. Meyer[4], D. J. Scheeres[4], D. C. Richardson[1], O. S. Barnouin[5], R. T. Daly[5], C. M. Ernst[5], E. E. Palmer[6], F. Ferrari[7], Y. Zhang[1], P. Michel[2], M. Hirabayashi[8], R. Nakano[8], M. Jutzi[9], S. Raducan[9], A. F. Cheng[5], and the DART Investigation Team, [1]University of Maryland, College Park, MD, USA (hagrusa@astro.umd.edu), [2]Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France, [3]Aristotle University of Thessaloniki, Thessaloniki, Greece, [4]University of Colorado, Boulder, CO, USA, [5]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, United States, [6]Planetary Science Institute, Tucson, AZ, USA, [7]Department of Aerospace Science and Technology, Politecnico di Milano, Milan, Italy, [8]Auburn University, Auburn, AL, USA, [9]University of Bern, Bern, Switzerland.

Introduction: On 26 September 2022, the Double Asteroid Redirection Test (DART) spacecraft successfully impacted Dimorphos, the secondary component of the Didymos binary asteroid [1]. The impact reduced the mutual orbit period by $33 \pm 1(3\sigma)$ min, corresponding to an instantaneous reduction in Dimorphos's along-track speed of $2.7 \pm 0.1(1\sigma)$ mm/s [2,3]. The change in Dimorphos's velocity corresponds to a possible momentum enhancement factor of $\beta = 2.2 - 4.9$, mainly depending on the unknown mass of Dimorphos [3]. The DART impact significantly perturbed both the orbital and rotational state of Dimorphos. Here, we use numerical simulations that fully account for spin-orbit coupling to study Dimorphos's excited post-impact rotation state resulting from its perturbed mutual orbit.

Previous studies demonstrated that Dimorphos's post-impact spin state is highly dependent on its own shape (i.e., moments of inertia) and the momentum enhancement factor, β, both of which were unknown quantities at the time [4]. Depending on Dimorphos's shape and the change in its orbit, it was predicted that Dimorphos would enter one of two possible rotation states: either stable libration or chaotic non-principal axis (NPA) rotation. NPA rotation can be triggered by possible resonances among the various frequencies of Dimorphos's motion, including its mean motion, free libration, precession, and nutation frequencies, which depend significantly on the body's shape and impact outcome. Based on newly available estimates for Dimorphos's pre-impact shape and the perturbation to Dimorphos's orbit [1-3], we revisit this prediction and estimate the probability that Dimorphos has entered NPA rotation due to the DART impact. We also examine the possibility that Dimorphos was already in an excited rotational state prior to the DART impact. We discuss the added complication that immediate impact-induced changes to Dimorphos's moments of inertia may significantly influence the dynamics [5]. The implications of Dimorphos's excited orbital and rotational state are discussed, including its effect on the system's secular evolution [6], interior structure [7], and granular motion on Dimorphos's surface [8], which will then be characterized in 2027 by the ESA Hera mission [9].

Preliminary Results: Based on DART's approach imagery, Dimorphos was found to have a shape very close to an oblate spheroid with semiaxis lengths of approximately $(a, b, c) = (88.5 \pm 1, 87 \pm 2, 58 \pm 1)$ m [1]. In Fig. 1, we show a preliminary suite of ~22,000 numerical simulations that propagate the fully coupled spin and orbital evolution of Dimorphos following the DART impact, given this new knowledge of Dimorphos's shape. The subplots show the maximum roll, pitch, and yaw angles achieved by Dimorphos over that time as a function of its axis ratios a/b and b/c. Depending on Dimorphos's dynamically equivalent ellipsoid, certain resonances can further excite the spin state, leading to NPA rotation and a departure from synchronous rotation. These simulations assume an idealized, head-on impact, simplifying the full three-dimensional momentum vector of the DART spacecraft and associated ejecta momentum. Furthermore, these simulations neglect any mass loss or shape change that result from cratering. Therefore, these results should be interpreted as a conservative estimate for the possible post-impact rotation state of Dimorphos.

Conclusions: The post-impact rotation state of Dimorphos has been significantly excited with a real possibility of chaotic NPA rotation. Simulations accounting for higher-order effects, such as the instantaneous torque from the slightly off-center impact, shape change, and mass loss, are currently underway to fully assess the likelihood of such a chaotic post-impact rotation state.

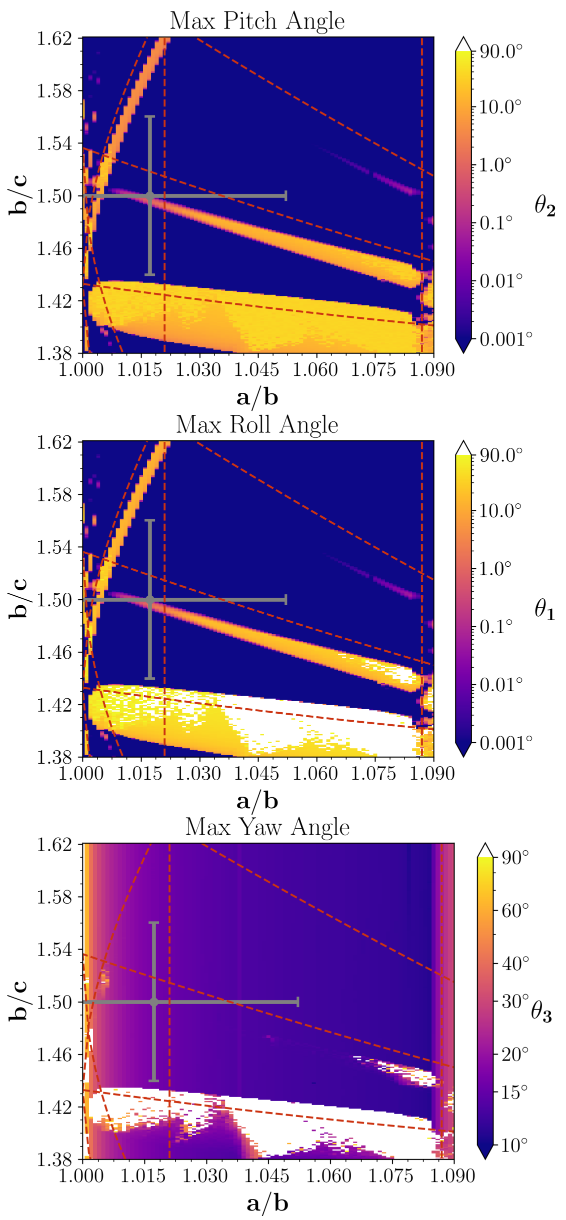

Figure 1: The maximum roll, pitch, and yaw angles achieved by Dimorphos as a function of its ellipsoidal axis ratios a/b and b/c for a 1-year post-impact simulation. These simulations assume an idealized, head-on DART impact and neglect any mass loss and changes to the moments of inertia resulting from cratering. As such, these preliminary results likely *underestimate* the possibility of Dimorphos entering NPA rotation following the DART impact. The red dashed lines are analytical predictions for destabilizing resonances from [10], while the grey crosshair marks the measurement and 1σ uncertainty of Dimorphos's triaxial shape [1]. We explore far outside of the 1σ region simply because Dimorphos's dynamically equivalent equal volume ellipsoid (DEEVE) shape does not necessarily have to correspond to its physical shape.

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