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Introduction: On 26 September 2022, the Double Asteroid Redirection Test (DART) spacecraft impacted the surface of Dimorphos, the ~150 m-size moonlet of the binary system (65803) Didymos (~780 m-size, [1]), allowing detailed surface characterization. Both DART and the Light Italian Cubesat for Imaging of Asteroids (LICIACube, [2]) provided direct observations of geological features, including lineaments, rocks’ fractures and/or cracks, boulders, craters and signs of mass movements. Here, we study Dimorphos boulders’ fractures to constrain their formation processes. In particular, we analyse Dimorphos’ fracture length distribution and direction to test the hypothesis that these fractures propagate via thermal fatigue.

Dataset: DRACO, the scientific camera onboard DART [3], imaged the surface of Dimorphos with a spatial resolution from few meters to a maximum of 5.5 cm. Here, we use the DRACO image taken 1 s before impact with a resolution of 5.5 cm to analyze Dimorphos boulders cracks, as shown in Fig. 1.

Figure 1. Dimorphos high resolution mosaic created with the final 10 DRACO images from 11.447 s to 0.856 s before the impact (pixel scale ranging between 34.9 cm/px and 2.6 cm/px).
Boulders cracks mapping and analysis: We mapped approximately 50 fractures with a length ranging from 1 to 10 m, investigating their length distribution and orientation. We derived a rose diagram showing an NW-SE preferred orientation (Figure 3), which may point to a thermal mechanism formation for the boulder cracks [4]. Indeed, on other asteroids, as Bennu and Ryugu, the evidence of preferential meridional orientation of boulders’ fractures is consistent with cracking induced by diurnal thermal cycling supporting the hypothesis that thermal fracturing plays an important role on asteroid surfaces in general [4, 5]. The fractures’ length distribution is well-fitted by an exponential law for lengths larger than 0.77 m, which is indicative of the important role of thermal stress in fracture propagation.

Thermophysical and thermal fatigue modelling: To assess the thermal fatigue hypothesis, we applied a Finite Element Method (FEM) thermophysical model [6] on three different boulders (Atabaque hosting 6 fractures and other two boulders hosting one and two fractures, respectively, Fig. 1). We then derived the diurnal and seasonal temperature evolution profiles finding a similar trend for all the three boulders. We input the solution from the thermophysical model into established thermal fatigue models to model the propagation of fractures in boulders in the direction towards the center of the asteroid (normal depth direction z) and in the direction of preferential propagation of fracture (horizontal fractures in direction x). In particular, thermal stresses generate the propagation of fractures faster in the horizontal direction with respect to the vertical one, constraining their development on Dimorphos’ boulders between 10-100 kyr.

Hence, we propose that the fractures observed on Dimorphos’ boulders are shallow and that the vertical propagation mode is not the dominant mode of fracture propagation. Indeed, the propagation of fractures along the boulder surface on Dimorphos may occur one to two orders of magnitude faster than in vertical direction (Myr).

Acknowledgments: This work was supported by the Italian Space Agency (ASI) within the LICIACube project (ASI-INAF agreement n. 2019-31-HH.0) and HERA project (ASI-INAF agreement n. 2022-8-HH.0). S.C. acknowledges funding from the Crosby Distinguished Postdoctoral Fellowship Program of the Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology. R.N. acknowledges support from NASA/FINESST, United States (NNH20ZDA001N/80NSSC21K1527). R.N. also would like to thank Joseph Iverson for assistance in conducting the thermophysical simulation. This work was supported by the DART mission, NASA Contract 80MSFC20D0004. SDR acknowledges support from the Swiss National Science Foundation (project number 200021_207359). P.M. acknowledges funding support from the French space agency CNES, ESA and The University of Tokyo. L.P. contribution was supported by the Margarita Salas postdoctoral grant funded by the Spanish Ministry of Universities – NextGenerationEU and CIAPOS/2022/066 postdoctoralgrant (European Social Fund). OK acknowledges funding support from the PRODEX program managed by the European Space Agency (ESA) with help of the Belgian Science Policy Office (BELSPO).