BOULDERS ON ASTEROIDS DIDYMOS AND DIMORPHOS: FUTURE DART-LICIACube OBSERVATIONS

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Introduction: Asteroid (65803) Didymos is a Near Earth S-type [1] asteroid of the Apollo group. It is a binary system characterized by a 780±30 m size primary, called Didymos, and a 164±18 m size secondary, called Dimorphos, orbiting at a distance of ~1.19 km [2]. The primary rotation period is 2.26 h [2], close to the 2.2 h disruption spin barrier (if the bulk density is less that 2.1 g/cm^3) [3], while the period of revolution of Dimorphos around the primary is 11.9217+0.0002 h [4]. This asteroid is the target of the NASA Double Asteroid Redirection Test mission (DART, [5]), whose main goal is to impact Dimorphos at a speed of 6.6 km/s during the September-October 2022 timeframe.

The DART-LICIACube mission: The camera onboard DART is called DRACO, *i.e.* the Didymos Reconnaissance and Asteroid Camera for Op-nav [6]: its main goals are to image Didymos for optical navigation, to resolve the two bodies and support the spacecraft autonomous navigation to Dimorphos, acquire images to constrain the size and shape of Dimorphos, and to locate the impact site precisely and characterize its local surface features. A complementary cubesat, called the Light Italian Cubesat for Imaging of Asteroids (LICIACube, [7]) will be released from DART ten days before the impact, and it will be autonomously guided through a flyby with closest approach (CA) distance of ~55 km from the target. LICIACube cameras LEIA (LICIACube Explorer Imaging for Asteroid - narrow angle camera) and LUKE (LICIACube Unit Key Explorer – wide angle camera) will then safely witness the redirection test *in-situ*, while its crater, as well as the ejecta and plume are being formed.

Blocks/boulders/pebbles on the Didymos-Dimorphos system: Boulders/large blocks on asteroids are mainly interpreted as produced by target fragmentation and excavation due to high-velocity impact processes. They are the largest fragments excavated during impact processes and are typically found within the crater or in its proximity, because they have not reached the escape velocity [8]. Instead, on rubble-pile asteroids boulders (typically the largest ones) are also products of the reaccumulation process that formed the minor body itself, and may not be correlated to the observed craters [9]. For both cases, these blocks provide information on impact cratering processes occurring on low gravity bodies or on their parent body disruption event: their size-frequency distribution (SFD) fitting indices are therefore pivotal to provide hints on the fragment/boulder formation and/or degradation processes.

Deriving boulder SFD and the corresponding power/exponential-law indices has been an important scientific topic addressed in several fly-by and orbital missions to minor bodies [e.g. 10-12]. For this reason, it will be accomplished on the Didymos-Dimorphos system as well.

The DRACO-LEIA expected observations: Four minutes before the impact the last DRACO image that contains all of Didymos will be taken, with an expected spatial scale of 7 m/pixel. Two minutes before impact, the last DRACO image containing any part of Didymos will be taken (Fig. 1), with a maximum resolution of 3.5 m [13]. DRACO will image all Dimorphos at ~50 cm/pixel ~17 seconds before the impact and it plans to return at least one higher-resolution image before impact. Such final image will have a pixel scale <15 cm/pixel [14]. With this dataset, it will be possible to identify the boulders SFD located on the illuminated imaged side of the primary down to sizes of ~11 to 21 m and compare it with previously observed SFD of other asteroids [9,15]. Instead, boulders ≥ 0.6-1.5 m will be identified on Dimorphos, hence returning the pre-impacted SFD context of the impact location.

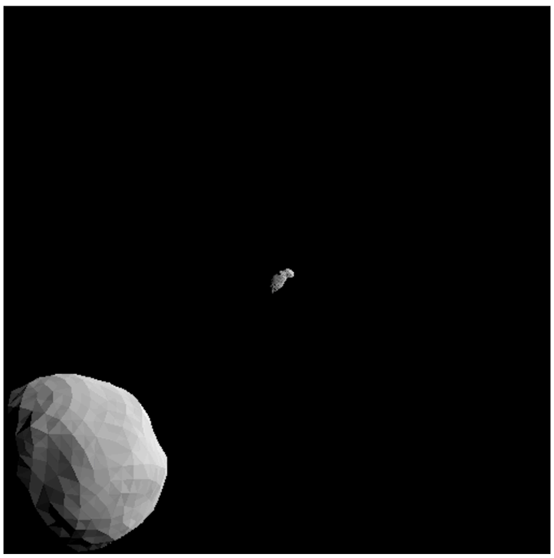

Fig. 1: Simulated view of the DRACO camera 129 seconds before impact. The shape used for Dimorphos is asteroid Itokawa, reduced in size to match the real dimensions.

During CA, the LICIACube/LEIA camera will observe the surface of Dimorphos getting few images with resolution between 1.4 and 2 m/px [7], Fig. 2. It is not yet sure if the DART crater will be observed through LEIA, since it may be close to the limb during CA (hence the challenging imaging condition), but if so, we will be able to identify all boulders ≥ 4.0-7.0 m located on the impacted side of Dimorphos, discerning those that have been generated/fragmented/moved after the DART impact from the ones previously imaged through DRACO.

Moreover, LEIA will image the non-impacted side of Dimorphos (not observed by DRACO) with resolutions ranging from 1.5 to 5 m: this will enable the characterization of the boulders SFD of the secondary down to 4.5 m. By comparing both the pre-, post- and non-impacted surface areas we will have the unique opportunity to witness how the boulders SFDs and densities/m^2 will change as a result of a well characterized, hypervelocity impact. We will therefore test if the generation of a crater results in a different power-law distribution of boulders than the one observed on other S-type asteroids, such as (433) Eros and (25143) Itokawa [8,9], as well as recently observed carbonaceous asteroids, (101955) Bennu [12] and (162173) Ryugu [15]. Also, the contrasts of boulder SFDs will shed light on the formation of binary asteroids.

Fig. 2: The S-type asteroid (25143) Itokawa observed with the Hayabusa/AMICA camera [16]. The spatial scale is ~1.4 m/pixel, similar to the one that LEIA will take of Dimorphos at CA.

Acknowledgments: This research was supported by the Italian Space Agency (ASI) within the LICIACube project (ASI-INAF agreement AC n. 2019-31-HH.0).

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