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Boulders Size-Frequency Distribution on binary asteroid (65803) Didymos: Expected results from LICIACube/LEIA and DART/DRACO cameras

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Introduction

Asteroid (65803) Didymos is an S-type [1] Apollo 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 [3], while the period of revolution of Dimorphos around the primary is 11.9217+0.0002 h [4]. This asteroid has been selected as the target of the Double Asteroid Redirection Test (DART, [5]), whose main goal is to impact Dimorphos at a speed of 6.6 km/s on September 30, 2022, thereby demonstrating the kinetic impactor technique and evaluating the resulting impulsive deflection.

The scientific 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 the target, and to locate the impact site precisely and characterize its local surface features. To complement such observations, the Light Italian Cubesat for Imaging of Asteroids (LICIACube, [7]) will be released from DART ten days before the impact, and autonomously guided through a flyby with closest approach 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.

Boulders SFD on Didymos 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 an impact 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 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]: it will be accomplished on the Didymos system as well.

Four minutes before the impact the last image that contains all of Didymos will be taken by DRACO, with an expected spatial scale of 7 m/pixel. 120 seconds before impact, the last DRACO image containing any part of Dydimos will be taken, with a maximum resolution of 3.5 m [13]. DRACO will image all of Dimorphos ~50 cm/pixel ~17 seconds before impact and plans to return at least one higher-resolution image before impact. These final image(s) will have pixel scales <15 cm/pixel [14]. Such images will provide the possibility 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 with sizes larger than 0.6-1.5 m will be identified on Dimorphos, hence returning the pre-impacted SFD context of the impact location.

At closest approach (CA), LICIACube/LEIA will image the surface of Dimorphos at 1.4 m/px [7]. If the DART crater will be observed through LEIA (it may be close to the limb during CA, hence the challenging imaging condition), we will be able to identify all boulders larger than 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. In addition, 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].

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