

**NEW GEOLOGIC MAP AND OBSERVATIONS OF THE DIDYMOS SURFACE USING DART/DRACO AND UNEXPLORED LICIAcube/LUKE IMAGES.** Tusberty Filippo<sup>1</sup>, Pajola Maurizio<sup>1</sup>, Penasa Luca<sup>1</sup>, Lucchetti Alice<sup>1</sup>, Beccarelli Joel<sup>2,1</sup>, Munaretto Giovanni<sup>1</sup>, Rossi Costanza<sup>1</sup>, DART and LICIAcube team. <sup>1</sup>INAF-OAPD Astronomical Observatory of Padova, vicolo dell'osservatorio, 5, 35142, Padova, Italy (filippo.tusberty@inaf.it); <sup>2</sup>Centro di Ateneo di Studi e Attività Spaziali – Giuseppe Colombo (CISAS), Padova, via Venezia 15, 35131 Padova, Italy.

**Introduction:** (65803) Didymos is a binary asteroid system of stony, Sq-type composition [1] that was recently explored during the NASA Double Asteroid Redirection Test (DART) mission [2]. The primary body Didymos has a maximum diameter of approximately 819 m, while its moonlet Dimorphos measures about 177 m in diameter [3]. On 11 September 2022 the ASI Light Italian CubeSat for Imaging of Asteroids (LICIAcube) was released with the main objective of acquiring images of the DART spacecraft impacting on the surface of Dimorphos [4]. LICIAcube is equipped with two imaging systems: the LICIAcube Explorer Imaging for Asteroid (LEIA), whose images were out of focus and are therefore not considered for this work, and the LICIAcube Unit Key Explorer (LUKE) [5]. The LUKE scientific operations started 29 s after the impact, during which sequences of three images with varying exposure times were acquired. In this phase, and particularly immediately following the closest approach, LUKE collected several images of the southern pole of Didymos, which was not previously imaged by the Didymos Reconnaissance and Asteroid Camera for Optical Navigation (DRACO) [6]. This dataset represents a novel resource that has not been exploited yet in earlier investigations of the asteroid's surface morphology. Here, we use these images to produce an updated geological map of Didymos, expanding the map presented in [1] also including the regions imaged by LUKE. The revised analysis reveals the presence of a candidate impact crater not identified in prior studies and allows for a refined boulder size frequency distribution (SFD) of the Didymos surface.

**Data and Methods:** To conduct this work we made extensive use of both DRACO and LUKE images. We selected four LUKE images (liciacube\_luke\_l2\_1664234225\_00002\_01; liCIACube\_luke\_l2\_1664234227\_01003\_01; liCIACube\_luke\_l2\_1664234229\_00005\_01; liCIACube\_luke\_l2\_1664234234\_00002\_01) with a pixel scale of 2.6 m/px to better interpret the geology of the studied area. We also used DRACO data to extend the study area as much as possible and to have a continuity with the first released geologic map [1]. In particular, we chose the image dart\_0401929842\_42894\_02\_iof because of its extensive coverage and its pixel scale of 6.34 m/pixel.

All these images have been analyzed both on Qgis and Small Body Mapping Tool (SBMT) [7], which we used to project the images on the 3D model of Didymos. This was pivotal to have a better understanding of the three-dimensional perspective of the body and, therefore, of the geological unit distribution. Afterwards, we used the SBMT tools to acquire high-resolution snapshots of the 3D model of Didymos overlaid by the DRACO and LUKE images. We acquired the snapshot from four different viewpoints (Fig. 1) starting from the [1] perspective (Fig. 1A) and then rotating the model toward the southern pole of Didymos (Fig. 1B, C, D). Therefore, we prepared four distinct, but spatially-connected, geological maps in order to give a three-dimensional perspective of the products.

To prepare the geologic maps we followed established methodologies [8] and used the Qgis *mappy* plugin [9]. To discriminate between different geological units, we used the abundance of visible boulders present on the studied surfaces. Areas containing a higher number of visible boulders appear rougher and more irregular, while areas with few or no visible boulders display smoother surfaces. We then defined three distinct units described below:

- **Rough unit:** encompasses areas characterized by the presence of boulders larger than 15 m, which are also visible at the DTM scale. These areas exhibit a highly rough and hummocky appearance.
- **Intermediate unit:** includes areas that appear smoother than the *rough* unit, although boulders larger than 15 m are still visible at the scale of LUKE and DRACO images.
- **Smooth unit:** includes areas that do not show any boulders both at the scale of the DTM, LUKE, nor DRACO images. We highlight that these regions may exhibit a non-flat topography but still appear smooth and not bumpy.

The “*not mapped*” areas are those with low resolution, distorted images, or missing data, which prevent a correct interpretation of the surface geology.

**Results and Discussions:** The four geological maps show Didymos as a body mainly characterised by a rough surface. Indeed, of the total area analysed, the most extensive unit is the *Rough* one, which covers about 71% of the mapped area, followed by the

*Intermediate* (23%) unit and the *Smooth* unit (6%). This roughness is most likely due to the extensive presence of large boulders across the majority of the surface of Didymos. On the other hand, some regions show smoother terrains, likely reflecting the absence of large boulders. These areas are completely circled by the *rough* regions, which extend through the vast majority of the studied surface.

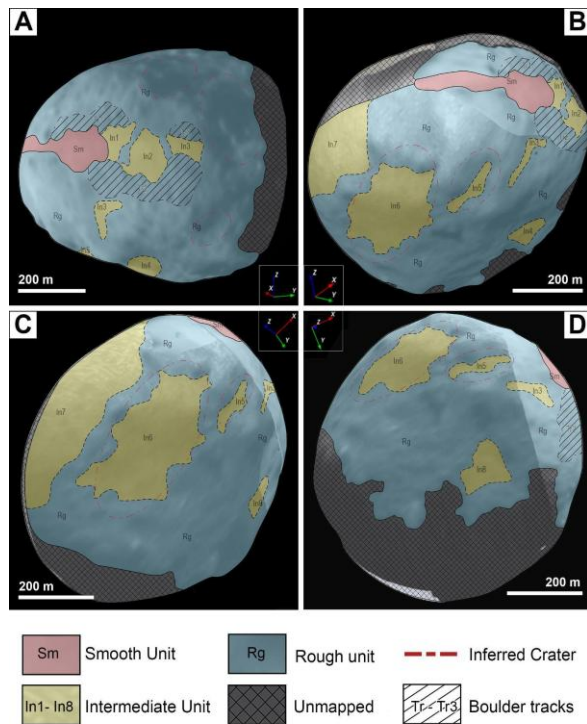


Fig. 1: The geologic map of Didymos seen from four different points of view: A) geologic map overlying the DRACO image oriented with the north up (Z+); B) geologic map overlying the LUKE and DRACO images combined; C) and D) geologic maps of the southern pole overlying the LUKE images.

The unique *Smooth* region is located in the equatorial region between 60W and 5E. It is ~400 m long and ~30-50 m wide, displaying an irregular linear-like shape. This specific shape can be due to regolith mass movement effects [1] linked to the dynamics of the equatorial region also supported by the presence of potential boulder tracks [10]. Nevertheless, our investigation is limited by a pixel scale of 2.5-6 m/px. Therefore, it is probable that these regions are characterized by accumulations of boulders with smaller sizes, not identifiable with the available images resolution.

In addition, a potential crater has been found in the area between ~50-160°W and ~10-70°S. This feature is 520 m long, 286 m wide and its elevation profile shows an elongated ellipsoidal shape with a depth of

~60 m. It is characterized by a smoother floor with the presence of very few boulders or bumps at the scale of the image. This wide depression is circled by raised rims mostly composed of large boulders and mounds arranged in an ellipsoidal shape. These properties suggest that this feature could be a crater. However, it might also just be a topographic depression, since its large size implies that some morphologic features should be more pronounced, and the lack of any high-resolution images currently prevents a definitive interpretation. The Hera mission will reach the (65803) Didymos system at the end of 2026 and will conduct high-resolution imaging of the surface of Didymos. The higher resolution data expected from the mission will reveal the composition of these uncertain regions.

**Future work:** The next step will be to analyze the boulder Size Frequency Distribution of Didymos, improving the first results of [11] by adding to these statistics also the boulders identified with the LUKE images. In addition, comparative studies between Didymos and other asteroids, such as Itokawa and Toutatis, will be further investigated. The updated version of this work including the results of this analysis will be presented at the conference.

**Acknowledgements:** This work was supported by the Istituto Nazionale di Astrofisica (INAF) with the mini grant project 2024 “Unveiling the Secrets of NEAs and Their Parent Bodies: A Surface Lithological Analysis”; and HERA project (ASI-INAF agreement n. 2022-8-HH.0).

**References:** [1] Barnouin, et al. (2024) *Nature Commu.*, 15(1), 6202. [2] Rivkin, A., et al. (2021). *PSJ*, 2(5), 173. [3] Ieva, S., et al. (2022). *PSJ*, 3(8), 183. [4] Dotto, E., et al. (2024). *Nature*, 627(8004), 505-509. [5] Dotto, E., et al. (2021). *PSS*, 199, 105185. [6] Fletcher Z. J., et al. (2018) Space Telescopes and Instrumentation [7] Ernst, C. M., et al. (2018) LPSC 49, abstract no. 1043. [8] Tusberty, F., et al. (2025) *Icarus*, 116744. [9] Penasa, L., et al. (2020) EPSC2020-1057. [10] Bigot, J., et al. (2024) *Nature Commu.*, 15(1), 6204. [11] Pajola et al. (2024) *Nature Commu.*