MAPPING ALBEDO VARIATIONS TO CONSTRAIN THE HISTORY OF THE DIDYMOS SYSTEM FROM DART AND LICIACUBE OBSERVATIONS. J. M. Sunshine[1], J. Rizos[1], T. L. Farnham[1], O. S. Barnouin[2], A. F. Cheng[2], R. T. Daly[2], C. M. Ernst[2], B. J. Buratti[3], T. Kohout[4], E. E. Palmer[5], J.Y. Li[5], P. A. Abell[6], E. Dotto[7], P. Hasselmann[7], M. Pajola[8], A. Lucchetti[8], P. Deshapriya[7], and the DART team, [1]University of Maryland, Dept. of Astronomy, College Park, MD (jess@astro.umd.edu), [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [3]Jet Propulsion Laboratory, Pasadena, CA, [4]University of Helsinki, Finland, [5]Plaentary Science Institute, Tucson, AZ, [6]NASA Johnson Space Center, Houston, TX, [7]INAF-Observatory of Rome, Rome, Italy, [8]INAF-Observatory of Padua, Padua, Italy.

Introduction: The Double Asteroid Redirection Test (DART) relied on its high-resolution, broad-band camera DRACO to successfully execute its impact experiment on September 26, 2022. While targeting Dimorphos, the ~150 m diameter moon of the Didymos binary asteroid system, DART also imaged the ~760 m diameter primary [1]. LICIACube, a ride-along CubeSat released from DART prior to impact, carried two cameras, LEIA and LUKE, pan and wide-angle RGB color cameras, respectively, to witness the impact and also image both bodies [2]. In addition to critical data that enabled and observed the impact, these cameras provided the highest spatial resolution data of any binary asteroid system and the first for near-Earth asteroids. Mapping and comparing albedo units on both the primary and secondary and placing them in the context of other S-type asteroids will help constrain the physical relationships and prior interactions between the two bodies and thus reveal the formational and evolutionary history of the Didymos system.

Albedo of the Didymos System: The albedo of Didymos and Dimorphos as a system has been observed telescopically [3]. These integrated observations, combined with the now known sizes of the bodies derived from spatially resolved DRACO images, result in a geometric albedo (0.55 µm) of 0.15 ± 0.02 [1]. This value is within the range of other S-types asteroids [4,5] but lower than average, which suggests that the Didymos systems may be more extreme than other S-type asteroids in terms of large-scale geomorphology (e.g., more boulders) and/or unknown properties of their surfaces (e.g., roughness or composition). Future efforts including photometric modeling will, for example determine roughness and shadowing parameters, which will help to constrain the origin of these differences and may thereby help explain the range of disk integrated albedos among S-type asteroids.

Photometric Corrections: Comparison of the brightness of planetary surfaces requires correction for variations in lighting and viewing geometries, after which true variations in photometric behavior can be modeled and linked to the physical properties of the asteroids [6]. These modeling efforts will ultimately be based on accurate shape models and orbital reconstructions; however, these data are still being developed for the DART project [1].

Empirical Approach. Here we report on empirical efforts to correct for viewing geometry and illumination changes. Brightness (I/F) of both bodies is evaluated as a function of incidence, emission, and phase angles based on preliminary reconstruction of the flyby. Brightness variations in DRACO data for both asteroids are dominated by a decrease in I/F with incidence angle, with additional small increases in I/F with phase and emission angles. For a preliminary correction of these

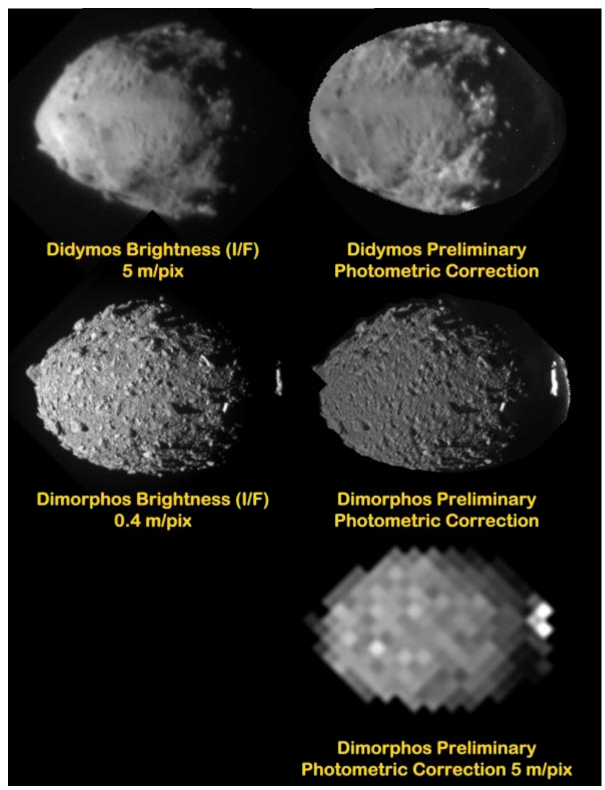

Figure 1. Left: Brightness (I/F) images of Didymos and Dimorphos acquired with DRACO. Right: Preliminary photometric corrections based on empirical normalization of lighting conditions. To facilitate comparisons, the photometric correction for Dimorphos is also shown using data acquired at the same resolution (5 m/pix) as the highest resolution data of Didymos.

photometric effects, the incidence, emission, and phase angles were each fit by a 3rd order polynomial. This was done for each body independently. The results provide an initial normalization of the images with respect to viewing geometry for each asteroid (Figure 1).

Preliminary Results: While improvements in the shape models and radiometric calibrations are on-going, our preliminary analyses of brightness differences in the Didymos system reveal that Didymos has a large, distinct, 15% darker, central unit that also appears to be smoother than its surrounding terrain. This unit may correspond to regions with fewer boulders and may be the result of mass movement [7,8].

In contrast, the surface of Dimorphos, despite the higher spatial resolution (5 m/pix vs. 0.4 m/pix) does not have any apparent albedo units or variations.

However, to better compare the two bodies, we examined images acquired at the same resolution (5m/pix). This ensures that geometric information (incidence, emission, and phase angles) is known at the same scale for both bodies. As shown in Figure 1, at the same pixel scale Dimorphos appears to be ~10% brighter than average Didymos. This difference suggests that the brighter, outer areas with visible boulders on Didymos may be more like the surface of Dimorphos. The central dark unit of Didymos is therefore unique within this binary system and cannot simply be an unresolved version of Dimorphos. It is not clear yet if the albedo contrast could be due to less large-scale roughness (fewer boulders) and/or if these differences are consistent with an origin resulting from material movement [7,8].

Evidence for Shock Features on Dimorphos. In the last complete, highest resolution (5.5 cm/pix) DRACO image before impact, significant variations in albedo within individual meter-scale boulders on the surface of Dimorphos are visible. As highlighted in Figure 2, these variations indicate the presence of breccias and veins. The high-resolution DRACO images allow us to observe the surface of an S-type asteroid at nearly same scales as our meteorite samples. Features seen with rocks on the surface of Dimorphos are consistent with shock darkening and shock melt veins commonly seen in L/LL chondrite meteorites [9,10], which sample similar composition asteroids. Such shock features require impact speeds prevalent in the main belt. Thus, the boulders on Dimorphos, a body that is the result of an unknowable number of accretionary events, likely preserve a record of impacts that occurred on its original, main belt asteroid. The proportion of dark and light breccias in ordinary chondrites varies greatly among, and within, samples and may help account for differences in disk averaged albedos among S-type asteroids. It is also possible that different surfaces have different cumulative history and therefore preserve different amounts of primary shock features.

Acknowledgments: This work was supported by NASA (Contract No. 80MSFC20D0004 to JHU/APL), the Italian Space Agency (ASI) within the LICIACube project (ASI-INAF agreement AC n. 2019-31-HH.0), ESA, CNES, and made possible by the dedication of the DART and LICIACube engineering teams. All DRACO images used here are available from NASA's PDS Small Body Node.

References: [1] Daly R. T. et al. (2023), *Nature* submitted. [2] Dotto, E. et al. (2021), *PSS*. [3] Rivkin, A. S. et al. (2021), *PSJ*. [4] Tedesco et al. (1989), *AJ*. [5] Pravec, P. et al. (2012), *Icarus*. [6] Bowell E. et al. (1989), *Asteroids II*. [7] Barnouin, O. S. et al. (2023), *LPSC54, this volume*. [8] Lucchetti, A. et al. (2023), this volume. [9] Britt D. T. and Pieters, C. M. (1994), *GCA*. [10] Kohout T. et al. (2020), *A&A*.

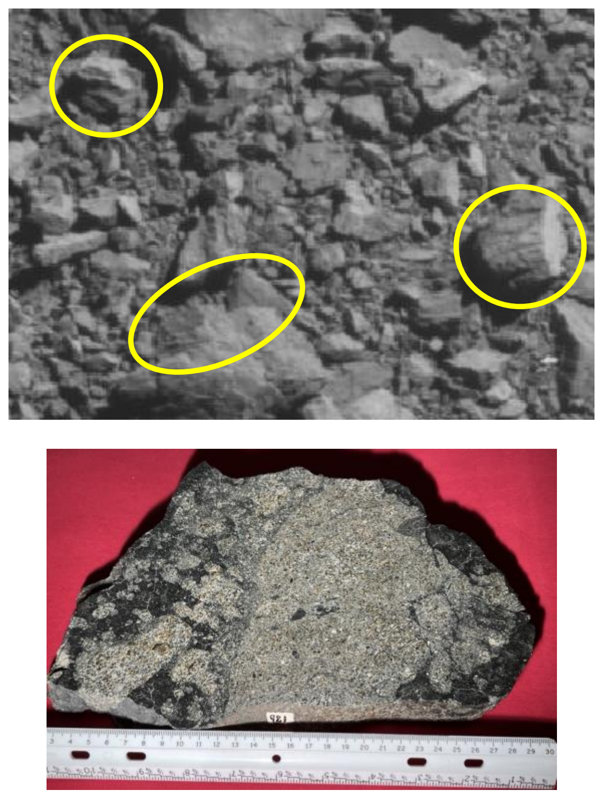

Figure 2. Meter-scale boulders on Dimorphos (top) contain albedo features consistent with brecciation, shock darkening, and melt veins commonly seen in ordinary chondrite meteorites [9,10], for example, as seen at similar scales in the Smithsonian National Museum of Natural History's large sample of Paragould, an LL5 chondrite that fell in 1930.