Albedo properties of Didymos and Dimorphos surface and ejecta plume through DART and LICIACube imaging.

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Introduction: The NASA/DART mission successfully accomplished the first planetary defense test on the 26th September 2022 when it impacted Dimorphos, the secondary object of the (65803) Didymos binary system. DART demonstrated the capabilities of the kinetic redirection technique. Dimorphos was hit by DART with velocity of 6.1 km/s, which produced a complex ejecta plume composed of filamentary streams extending roughly 10 km from the surface just hundreds of seconds after impact [1]. Before the impact, DRACO imager onboard DART provided near-real-time images during the fast approach phase, unveiling the surface of Dimorphos at very small spatial resolution in a single phase angle of 59°. The first seconds to minutes into the event were witnessed by the LEIA and LUKE instruments of the Italian Space Agency CubeSat LICIACube [2]. Both cameras captured hundreds of images during the fly-by maneuver, with the closest approach of about 57 km from Dimorphos. The disk-resolved data obtained has the largest phase angle coverage, ranging from 43° to 118°.

Methodology: With this large phase angle coverage and spatial resolution of the target's surface, combined with ancillary data such as trajectories and shape models, it is possible to retrieve the observational geometries necessary for testing photometric surface reflectance models [3,4,5]. The mid-to-high phase angles of these images are suitable for constraining the surface roughness, the asymmetric factor between scattering lobes, and also the single-scattering albedo.

For the ejecta analysis, we rely on the outputs of dynamical simulations performed using LICEI to propagate the ejecta initialized from Housen & Holsapple scaling laws [6,7,8] and the optical constants and phase function from laboratory measurements of analog compositions to understand the grains size distribution, velocity and spatial distribution from the brightness radial distribution derived from LICIACube observations.

To provide support and analyze the broad grain size distribution range expected in the plume, we worked on synthetic images from the combination of two numerical codes covering two different size regimes: (i) The Mishchenko radiative transfer code [9] for Mie-Lorentz scattering distribution (~0.5-80 microns size in visible wavelength range) with Percus-Yevick filling factor correction (called RTT-PM) to model the optically thick portion of the plume; (ii) the Muinonen geometric optics code [10] for diverse particle shapes and sizes higher than 100 microns to a few millimeters. Interactions are only resolved between the optically thick Mie-scattering cloud and the >100 microns particles, without coherence effects.

This analysis is of ultimate importance to constrain the mass and scattering properties of the ejecta. At the same time, it is important for inferring the dust average size surrounding the binary system, that directly contributes on the increase in magnitude after the impact [11]. Ground-based observations reveal a significant sunlight scattering that required a significant amount of micron-sized dust.

Results: Preliminary tests with the Hapke model [3] on DRACO Dimorphos data using MCMC Variational Inference [12], reveal a surface with photometric properties similar to other S-type asteroids. We report a preliminary global single-scattering albedo of 0.2±0.03 and roughness slope of 33±12 deg.

Dimorphos displays very bright apparent albedo units that can be related to differences in macroscopic roughness slope as well as single-scattering albedo. The single-scattering albedo is tightly related to composition while roughness can be related to matrix average grain size and material brittleness. High spatial resolution images obtained three seconds before collision show that many apparent high albedo feature can be related to oblique observation angle of boulder faces bearing different textures and very small unresolved bright units (Fig.1).

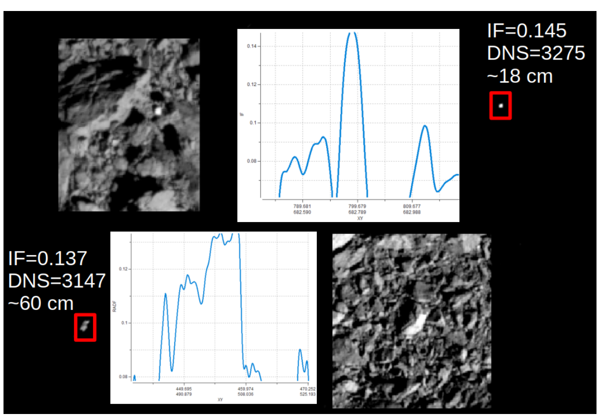

Fig 1: Example of some albedo variation present at the image DRACO from 2022-09-26 UT 23:14:21, taken about 11 km from Dimorphos and 3 seconds before the impact.

Ejecta radial brightness profile displays a monotonic slope between 0.5 to 1.7 km from the photocenter (Fig.2). Given that single-scattering is the dominant mechanism tens of seconds after impact, the profile mostly depends on single-scattering albedo and optical depth. The compositional albedo controls the curve radiance offset (as seen by the comparison with different compositions in the Fig.2) while variance in optical depth is the main parameter for the brightness slope with distance. Structures and inhomogeneities in the ejecta plume will translate as "bumps" and "oscillations" in the radial profile. In the visible light range, the lack of material relates to optical thinness, revealing where models must improve to filling-in the plume accordingly.

Finally, the cross-analysis between surface and ejecta is promising. Assuming similar siliceous composition, the analysis can constrains the single-scattering albedo of the surface/ejecta material as well as better understanding the physical properties of the ejecta's largest components, such as pebbles and boulders-like blocks, thus improving our knowledge about the dynamics of the event.

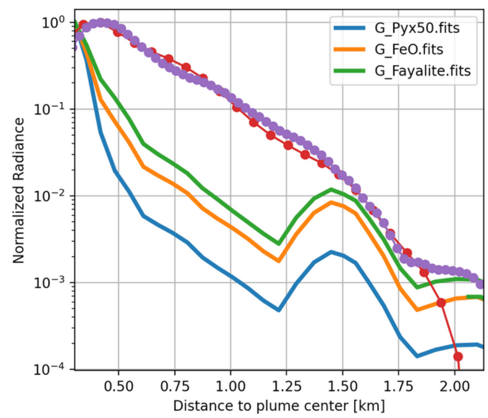

Fig. 2: LUKE GREEN normalized radial radiance for images taken at 87s and 181s after impact (violet and red dotted line, exptime=0.01s) compared to profiles from synthetic images from a 1 million-particle LICEI simulation computed for orthopyroxene, iron oxide and Olivine, components of siliceous composition. Phase angle ranges between 50 – 55 deg. Dimorphos and Didymos are masked from data points.

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