Characterizing the Properties of the DART Dust Ejecta Using 3D Radiative Transfer Modeling

Ludmilla Kolokolova, Yaeji Kim
University of Maryland, College Park, MD, USA

On September 26, 2022, the DART spacecraft impacted Dimorphos, the secondary component of the Didymos binary asteroid system, generating a substantial dust ejecta [1]. The Italian Space Agency's LICIACube, deployed as a follow-up observer, captured this event with its LEIA and LUKE cameras. To characterize the physical properties of the ejecta dust and their temporal variations as observed in post-impact LICIACube images, we have simulated the ejecta plume using the 3D radiative transfer code Hyperion (https://www.hyperion-rt.org/). Hyperion employs the Monte Carlo technique to simulate photon propagation through a scattering medium, accounting for multiple scattering effects. Dust modeling parameters include the single-scattering albedo, brightness and polarization phase functions, and the cross-sectional properties of dust particles, defined by their size and number density. These were modeled assuming a typical S-type asteroid composition for Dimorphos. We adopted a single-scattering albedo of 0.55 and used brightness and polarization phase functions based on laboratory measurements of irregular silicate grains spanning sizes from microns to millimeters [2, 3]. The ejecta plume was modeled as a hollow cone, characterized by impact location, tilt, and opening angle. Our current best-fit model reproduces the LUKE image taken 175 seconds after impact, with a focus on the near-surface region of Dimorphos. Comparison between observed and modeled brightness profiles provides constraints on the dust particle size distribution and number density, as well as their spatial variation. Fitting the observed radiance values across the plume allows us to refine the number density estimates and derive the mass distribution within the plume.

The developed numerical framework can serve as a template for characterizing dust in active asteroids, particularly in optically thick events, enabling constraints on dust size distribution, number density, and mass loss.

[1] Cheng, A.F., et al., 2023, Nature, 616(7957), 457-460.

[2] Munoz, O., et al., 2020, ApJ Suppl. Series, 247,19.

[3] Lolachi, R., et al., 2023, PSJ, 4, 24.