OPTICAL CHARACTERIZATION MODEL OF THE DART IMPACT EJECTA PLUME R. Lolachi[1,2,3], D. A. Glenar[1,2,3] and T. J. Stubbs[2]; [1]University of Maryland, Baltimore Co., Baltimore, MD (rlolachi@umbc.edu); [2]NASA Goddard Space Flight Center, Greenbelt, MD; [3]Center for Research and Exploration in Space Science and Technology, NASA/GSFC, Greenbelt, MD.

Introduction: The Double Asteroid Redirection Test (DART) mission is the world's first planetary defense mission. Reaching the binary (65803) Didymos-Dimorphos asteroid system in late September or early October 2022, it aims to change the orbit of the secondary member, Dimorphos, through kinetic impact deflection. The spacecraft will hit the 160 m diameter Dimorphos at a speed of approximately 6 km s^{-1} with the objective of changing its orbital period about Didymos by at least 73 s and creating an impact ejecta plume in the process (Fig. 1). These events will be observed both from Earth and by its ride-along companion SmallSat, LICIACube. These observations will be used to determine and understand the momentum transfer efficiency of the impact [1].

The resulting plume properties, including ejecta momentum and consequently momentum transfer efficiency are controlled by several global factors related to the asteroid material: strength, porosity (micro- and macroscopic), cohesiveness (do particles stick together?), and internal structure (e.g., is it a "rubble pile"? is there a regolith layer present?) [2,3]. However, factors local to the impact site can also play a major role. For instance, the value for transfer efficiency can change dramatically depending on whether DART impacts into a boulder or regolith [4].

One method of characterizing the impact ejecta is via optical observations of the evolving impact plume brightness coupled with radiative transfer reconstructions of sunlight scattering by ejecta particles. This approach can give information about composition, and the developing spatial and mass distributions of ejecta material. Using radiative transfer models to analyze and reconstruct an impact plume has a precedent. Previously, simulations were conducted using results from the Deep Impact mission in order

reconstruct the plume 1 s after impact in order to analyze its composition [5].

For DART, an initial radiative transfer prediction study of the LICIACube flyby observations was carried out by the mission team [1]. Estimates for geometric optical depth of the impact plume, as well as order-of-magnitude approximations for plume surface brightness were made, consistent with the measured Didymos geometric albedo of 0.15 [6]. These estimates were made assuming large, isolated plume particles, i.e., extinction coefficient of ∼2, an assumed isotropic phase function and single scattering. Unfortunately, if the same methodology is applied to reconstructions of the actual plume observations it is likely to result in large radiance differences and misinterpretation of ejecta properties. This is because it is vital to any such modelling effort to have a realistic treatment of the plume particle scattering properties, as well as the effects of large optical depth.

Using the flyby geometry of the study (Fig. 2) [1] we have performed our own reconstructions of the DART impact ejecta plume observations combining a 3D plume geometry, realistic phase function and the multiple-scattering radiative transfer software DISORT [7].

Geometry: A summary of the LICIACube flyby geometry is given in Fig. 2, which is the same impact and coordinate geometry as used in the DART team analysis [1]. The expanding impact plume is modeled as a hollow cone with interior angle of 90°. The DART velocity vector forms the y-axis, with predicted relative velocity v_F of 6.6 km s^{-1}, which impacts Dimorphos normal to its surface so that y bisects the evolving ejecta cone. LICIACube flies parallel and behind DART, forming the x-y coordinate plane, with the approach vector defining the x-axis. During most of the
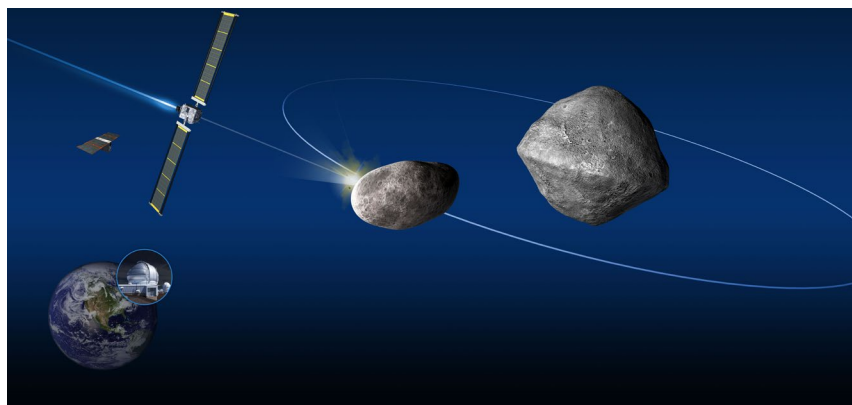

Figure 1: *DART Impact & LICIACube Flyby:* Concept art showing collision of the DART spacecraft into Dimorphos, moon of asteroid Didymos. This will result in: (i) an impact ejecta plume that will be observed by LICIACube; and (ii) a measurable change in orbital period for Dimorphos about Didymos. The impact will also be observed from Earth.
Credit: NASA/JHUAPL.

approach, LICIACube views scattered sunlight from the interior surface of the outward expanding plume. This geometry holds until the spacecraft crosses the extension of the plume surface, at which point there is an abrupt change in plume transmittance and scattering behavior seen by the observer. Between plume plane crossings, the line of sight passes through both plume layers in tandem, before again viewing separate surfaces.

Plume Particles: One plausible model for plume particles is impact fragments with reflectance properties similar to Didymos, which has a known geometric albedo $A_G = 0.15$ [6]. Implicitly, we assume small, opaque spheres with scattering surfaces, characterized by a Lommel-Seeliger phase function, typical of low-reflectance solar system objects [8]. Real impact fragments will probably be irregular and possibly porous. Approximate corrections for these effects can be made by geometric codes for computing the reflectance from irregular shapes, followed by orientation averaging.

Model & Discussion: Using the geometry outlined above we conducted line of sight simulations for normal geometric optical depths ranging from 0.01 to 10, for two cases: a) using our realistic scattering plume particles and b) using the simplifying scattering assumptions of the DART team [1]. It was found that this yielded differences in plume surface brightness exceeding an order of magnitude in the worst cases. This result highlights the importance of a realistic scattering parametrization and modelling regime.

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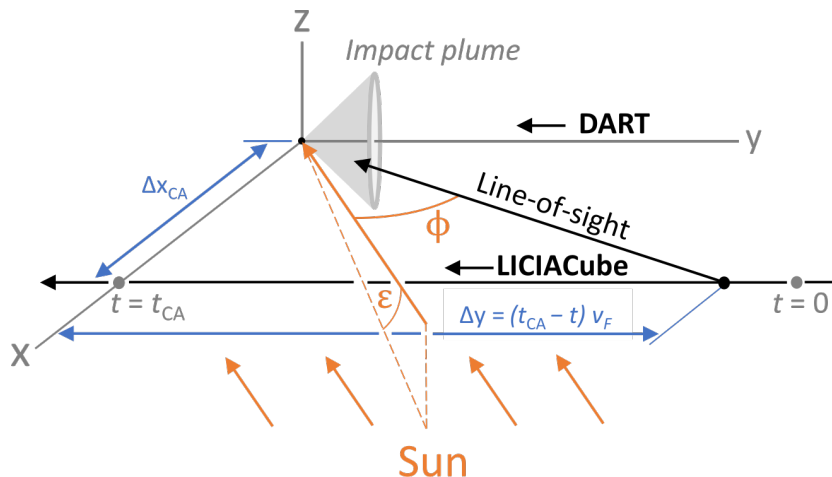

Figure 2: *LICIACube Flyby Geometry (based on [1]):* Origin at impact and ejecta plume centered on *y*-axis. Diagram shows position of LICIACube as a function of time following impact. v_F is relative velocity, Δx_{CA} is distance from origin at closest approach, ϕ is the phase angle observed at LICIACube (where $\phi = \pi - \theta_{sc}$ and θ_{sc} is the scattering angle), and ε is Sun elevation angle.