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# Synthetic Images and Colours of the Dimorphos Asteroid Ejecta Plume as seen from the LICIACube spacecraft

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## Introduction

The NASA Double Asteroid Redirection Test (DART) mission will be the first test to check an asteroid deflection by a kinetic impactor. The target of DART mission is Dimorphos the secondary element of the (65803) Didymos binary asteroid system, and the impact is expected in late September – early October, 2022 [1] The DART S/C will carry a 6U cubesat called LICIACube (Light Italian Cubesat for Imaging of Asteroid) [2], provided by the Italian Space Agency, with the aim to collect pictures of the impact's effects. On board LICIAcube will be hosted 2 camera payloads: LEIA a panchromatic (400-900nm Filter, 2.9x2.9° FOV) Narrow Angle Camera and LUKE a RGB (Bayer color filter, 4.8 x 9.15° FOV). LICIACube will be able to acquire the structure and evolution of the DART impact ejecta plume and will obtain high-resolution images and 2 colours data (B-G, G-R) of the surfaces of both bodies and the plume.

In order to check the imaging capability and to optimize the fast scientific phase of LICIACube, the LICIACube team performed simulations of pictures' acquisition. In these simulations, considering the specifications of the 2 optical payloads and the foreseen mission design, we reconstructed synthetic images mainly of the plume. Since the study of the plume and its evolution is one of the main scientific goal of the mission we performed a scattering modelling of the ejecta in order to invert the future photometric data deriving hints on the intimate nature of the dust particles released by the impact.

## Plume simulated Images and column density

With the two-fold aim of set the operative parameters for the Payloads and to understand the information retrievable by the images of the evolving plume we started an imaging simulation activities taking into account:

- LICIAcube mission design [3] (Trajectory, Speed, illumination conditions)
- Payloads optical characteristics

The plume evolution was simplified assuming:

- Non colliding particles during the plume evolution;
- A speed distribution in the plume given by eq:

$$v = U\,C_1 \left[\frac{x}{a} \quad \left(\frac{\rho}{\delta}\right)^{\nu}\right]^{-\frac{1}{\mu}} \left(1 - \frac{x}{n_2 R}\right)^{p}, \quad n_1 a \le x \le n_2 R$$

Where x is the distance on Dimorphos surface from the DART impact point and the other parameters used, considering as main material of asteroid system the cemented basalt, are reported in table:

| $a$ (m) | $R$ (m) | δ (g/cc) | ρ (g/cc) | μ | $C_1$ | k | p | ν | $n_1$ | $n_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 10 | 0.57 | 2.6 | 0.46 | 0.18 | 0.3 | 0.3 | 0.4 | 1.2 | 1 |

We considered the most representative 3 size bins for what concerns the ejected mass, the expected total number of particles are reported in table:

| | Size range (m) | Total number |
|---|---|---|
| $SR_1$ | $10^{-2} - 10^{-1}$ | $3.44 \times 10^{7}$ |
| $SR_2$ | $10^{-3} - 10^{-2}$ | $2.17 \times 10^{10}$ |
| $SR_3$ | $10^{-4} - 10^{-3}$ | $1.37 \times 10^{13}$ |

In Figure 1 is reported the simulated image obtained considering the LICIACube trajectory 50s before the close approach (about 110 s after the DART impact).

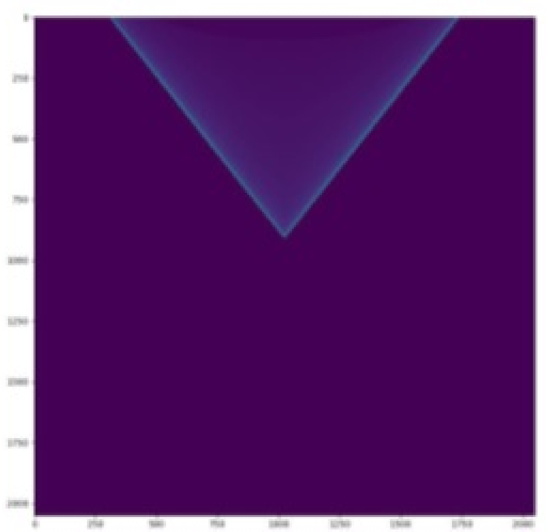

*Figure 1 Plume simulated image relative values for irradiance*

Once the simulated column density image was obtained, we added a scattering simulation considering spherical dust particles and using a Mie code well suited for large particles approaching the geometric optics regime [4]. In this way we were able to translate column densities in luminous fluxes measured by the instrument using a methodology described in the next section.

**Plume colours scattering modelling**

RGB data of the ejecta plume can be used to derive hints on the physical properties of the ejected particles through scattering modelling of the measured two colours (B-G, G-R) and the phase function versus the phase angle of observation α.

Given the intensity of solar light incident on the plume's single particle $I_{inc}$,, considering the incident solar light as unpolarized, the intensity of light scattered by the particle at α, $I_{sca}$ is given by [5]:

$$I_{sca}(\alpha) = \frac{1}{k^2 r^2} S_{11}(\alpha) I_{inc}$$

where $S_{11}(\alpha)$ is the first element of the 4X4 scattering Müller matrix, k=2π/λ is the wave number, and r is the distance between the particle and the observer. In this case:

$$I_{inc} = \frac{F_{Sun}}{r_h^2} \pi a^2$$

being $F_{Sun}$ the solar flux at 1 AU, $r_h$ the heliocentric distance of the dust particle, and a its radius.

The Mie code provides the complete scattering matrix once the dimension of the particle and its composition in terms of the complex refractive index of the material at the considered wavelength are given as input. We used largely referenced laboratory data on basaltic materials to obtain the optical properties of the dust particles [6]. This composition is used to model the dust particles residing on the asteroid surface [1], [2].

Then, in order to find the intensity due to the scattering of a single particle measured by the instrument at phase angle α, we convolved $I_{sca}$ with the photometric response of the instrument. For a generic filter, such measured intensity is  where Resp is the photometric response of the instrument extended throughout the bandpass of the filter. This response is a known product of several factors as the entrance pupil of the system, the reflectivity of the optics, the transmission curve of the filter, the quantum efficiency of the detector, and the exposure time.

Synthetic colours of the dust particles can therefore being computed being the generic color A-B = $-2.5\log(I_A/I_B)$. We performed sample scattering colour calculations varying the particle size from 0.1 micron to 1 cm.

Small particles provide extremely variable colours due to the strong influence of scattering resonances being the incident wavelength comparable with the size of the particles themselves. Colours get stable for a larger interval of phase angle proportionally to the increase of the size. Observations of stable colours in the plume during LICIACube flyby will be indicative of particles larger than 100 micron. At the same time, large basalt particles provide a flatter phase function at intermediate and small phase angles than smaller particles.

Combined observations of the plume phase function and colour will therefore effectively constrain the size of the ejected particles providing theoretical inputs to the dynamical models.

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