Constraining the ejecta cone geometry following DART impact on Dimorphos using LICIACube data

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Introduction

The Italian cubesat LICIACube [1] successfully observed the intended impact of the NASA Double Asteroid Redirection Test (DART) spacecraft on 26th September 2022 and acquired images of the ensuing ejecta cone. The impact successfully demonstrated the possibility of changing the orbit of the asteroid Dimorphos around the asteroid Didymos. By analysing the LICIACube images obtained by the LUKE instrument, we characterized the axis and the aperture angle of the observed ejecta cone. The solution of the ejecta cone orientation is fundamental to calculating the effectiveness of the impact in deflecting the target object off its original orbit, as momentum is transferred by means of escaping ejecta material.

Methodology

Using a sequence of LUKE images where the ejecta cone can be observed in a projected side-on profile (Fig.1) and using the geometrical relation between a cone and its projection onto a plane (Fig. 2), we derived an upper limit for the aperture angle of the cone. From Eq.1, which relates the orientation of the cone and its projection onto a plane, it is possible to see that the highest possible value of α is obtained when θ is 0°. Hence, looking at the LUKE observations, we placed an upper limit of 140° for the cone aperture angle. Then, using the relation in Eq.1 for image IDs 1-5, we developed a system of nonlinear equations to be numerically solved to recover the axis and the aperture angle of the ejecta cone.

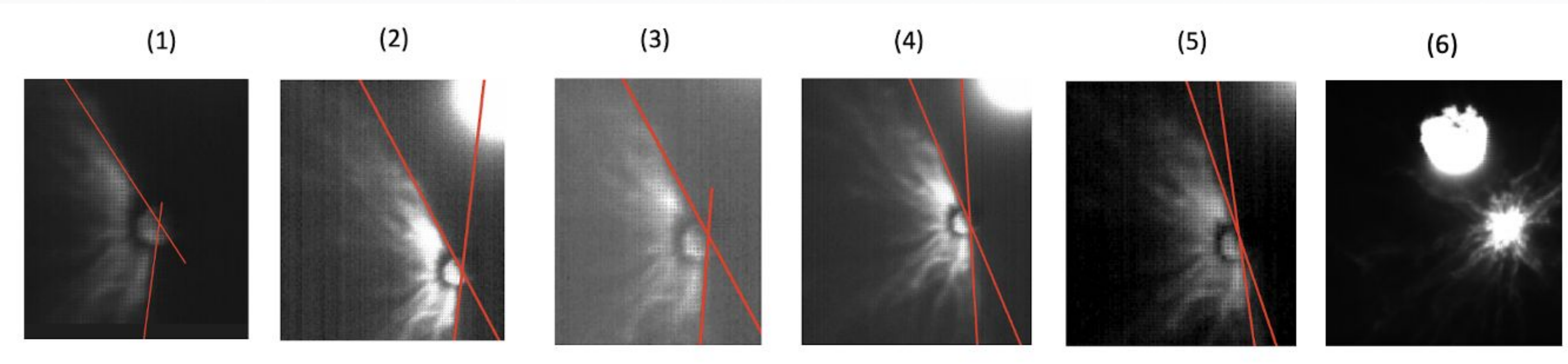

Fig. 1. Cropped LUKE images that were used for the analysis. The red lines in panels 1-5 indicate the slant axes of the ejecta cone that were used to measure the projected aperture angle 2δ. Panel 6 shows the ejecta cone in a different geometry than those in panels 1-5, which was used as a discriminator when accepting or rejecting candidate solutions for the ejecta cone. Image IDs correspond to those given in Table 1.

Table 1. Ancillary information of the LUKE images that went into the analysis.

Image ID	Timestamp	LUKE spatial resolution (m/px)	Exp. time (ms)	measured projected cone aperture angle 2δ (±1°) (deg)
(1)	2022-09-26T23:17:18.000	5.5	0.5	140
(2)	2022-09-26T23:17:19.100	5.9	0.3	145
(3)	2022-09-26T23:17:20.000	6.2	0.2	147
(4)	2022-09-26T23:17:21.000	6.5	0.7	160
(5)	2022-09-26T23:17:22.000	6.9	0.3	170
(6)	2022-09-26T23:16:56.004	8.5	3	N/A

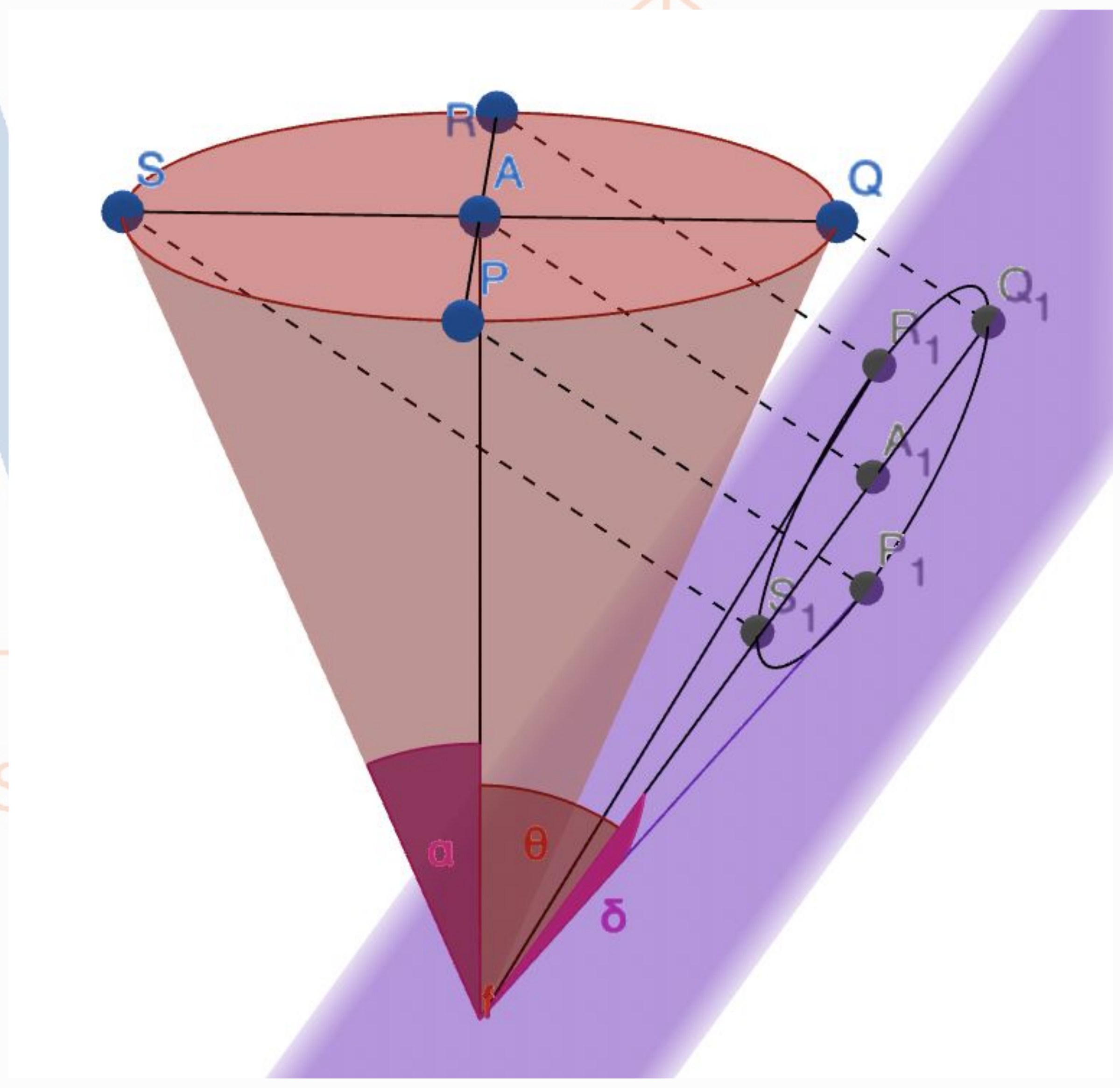

Fig.2. An axisymmetric cone with a half angle of α and its projection onto a plane which makes an angle of θ with the cone axis. δ is the half angle of the projected cone.

$$\tan\alpha = \frac{\tan\delta\ \cos\theta}{\sqrt{1+\tan^2\delta\ \sin^2\theta}} \quad \textbf{(1)}$$

For all the candidate solutions returned by solving unique systems of equations, based on five LUKE observations, we generated synthetic images with the solved ejecta cone at the same original LUKE observing geometries to reject or accept the solutions. To achieve this, image ID 6 was fundamental, as it corresponds to a very different geometry than the image IDs 1-5.

Results

The final solution for the ejecta cone axis and aperture angle is given in [2] and it is compatible with the solution in [3] derived using LICIACube and Hubble Space Telescope data.

References

[1] Dotto, E. et al., Planet. Space Sci. 199, 105185 (2021)
[2] Dotto, E. et al., Nature (submitted) (2023)
[3] Cheng, A.F. et al., Nature (in press) (2023)

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