

MONTE CARLO MODELING OF THE DUST EJECTA GENERATED BY THE DART IMPACT ON DIMORPHOS SURFACE

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Abstract

On September 26th 2022, the NASA/DART spacecraft impacted on Dimorphos, the secondary asteroid component of the (65803) Didymos binary system. The impact generated an extensive cloud of dust debris that evolved into a comet-like dust coma and tail, in a way similar to some active asteroids, as we had predicted in advance [1,2]. The tail is still detectable after six months since the impact event. In order to assess the physical properties and mass of the ejecta, we have developed a Monte Carlo model for the dynamics of the dust particles, including the computation of the dust coma and tail brightness images as a function of time. The resulting synthetic images are then compared to the high spatial resolution Hubble Space Telescope images [3].

Dust Tail Model

The dust tail model is based on the detailed dynamical evolution of the dust particles ejected from Dimorphos. The dynamical code takes into account the gravitational fields of Dimorphos, Didymos, and the Sun, as well as the solar radiation pressure [1]. A large amount of particles are emitted from Dimorphos surface following a hollow conical pattern with axis direction RA=137°, DEC=19°. The cone walls are assumed at having 10° in thickness. The particles are distributed following a broken power-law of index -2.5 from $r=5 \mu\text{m}$ up to $r=3 \text{ mm}$, and then an index of -3.7 up to the maximum size, set to $r=5 \text{ cm}$. The speeds of the particles are distributed into two-components, one of slow-moving particles with size-independent speeds near Dimorphos escape speed, and another fast-moving size-dependent ($\propto 1/\sqrt{r}$) component with speeds up to 40 m/s for

the smallest particles. The very fast speed ejecta ($\approx 2 \text{ km/s}$) is not taken here into account, as it disperses quickly in space and does not contribute to the images.

Discussion and Conclusion

Many of the features observed in the acquired images are simulated in the synthetic images (Figure 1).

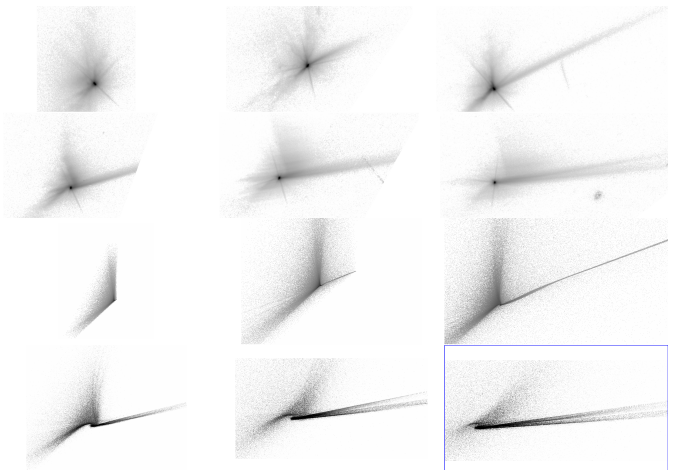


Figure 1. Upper two rows, HST observations of the DART ejecta. Lower two rows, synthetic images generated at the same dates. Dates are 2022 09/27.05, 09/27.31, 09/28.11, 10/01.69, 10/05.79, and 10/08.83.

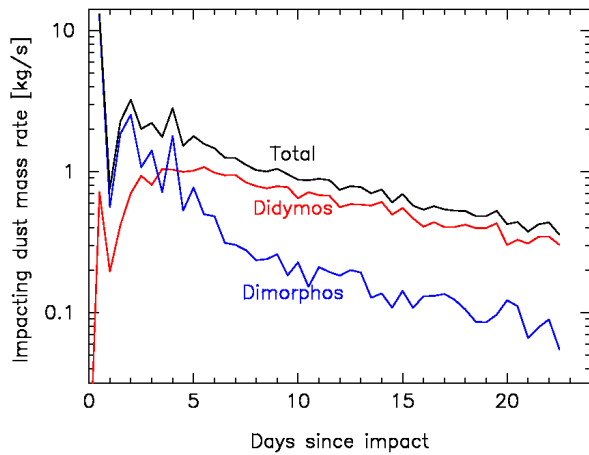


Figure 2. Impacting dust mass rates on Didymos (red line) and Dimorphos (blue line), and the sum (black line), as a function of time since impact.

Thus, the ejecta cone, and the antisolar double tail are well captured in the simulations. The northern component of the double tail is simulated assuming an impulsive isotropic ejection of material at escape velocity approximately 6 days after the main event, possibly associated to impacting particles on Didymos/Dimorphos. In fact, the impacting mass on Didymos peaks 5.5 days after impact (Figure 2), with larger impacting speeds (median value of 0.5 m/s) than those particles impacting on Dimorphos (0.09 m/s) suggesting that those Didymos falling back particles could be associated to the formation of the northern component of the tail.

Figure 3 shows how the curved ejecta streams towards north and southwest are quite well mimicked in the synthetic images. However, the evolution of these features is not closely matched by the model, as seen in the lower row of Figure 1, right panel, mainly in the 10/05.79 and 10/8.83 images. Northward of the tail the diffuse ejecta points to the wrong direction in the model (North-West instead of North-East). This might be suggesting that processes that are not being taken into account in the model like disruption or fragmentation of particles might be taking place. Further modeling in this direction is clearly needed to explain the whole picture.

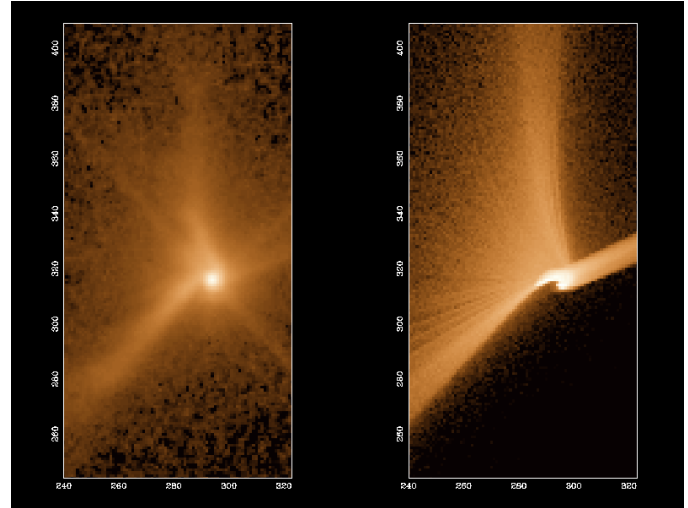


Figure 3. Innermost region of image 09/28.11. Left panel, HST observation. Right panel, model.

References

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