The Properties and Evolution of the Dust Ejecta Produced by the DART Impact

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NASA's Double Asteroid Redirection Test (DART) mission successfully impacted asteroid Dimorphos on September 26, 2022. This event marked the first-ever opportunity to directly observe both the excavation and the subsequent evolution of dust ejecta resulting from a planetary-scale impact on an asteroid. The data collected from this collision will not only enhance our understanding of asteroid impact mechanics, but also provide insights into the nature of dust emissions from active asteroids.

The DART impact ejecta contains three components: a fast jetting material expanding at ~15 km/s, a plume moving at ~1.5 km/s, and the dust and boulders ejected at speeds up to a few 100s m/s. Here we focus on the results about the dust ejecta, including the m-sized boulders, as observed by Hubble Space Telescope and ground-based telescopes. The dynamics of the dust ejecta is dominated by the particle size, ejection speed, and direction under the influence of solar gravity, the gravity of Didymos, and solar radiation pressure (SRP). The dust and boulders ejected at speeds exceeding a few m/s directly escape the binary system, maintaining their initial trajectories and forming a cone-shaped morphology. In contrast, slower ejecta with speeds under ~1 m/s is appreciably influenced by the gravity of Didymos, resulting in curved and rotating features a few days post-impact – a unique characteristic of ejecta from the satellite in a binary system. Additionally, SRP push the ejecta toward the antisolar direction, continuously modifying the cone morphology, leading to a wing-like structure with overlapping striae. The slowest dust forms a long, narrow tail starting from ~T+3 hours and lasting over 9 months after the impact. Modeling indicates µm- to cm-sized particles in the tail with a broken power law size frequency distribution with slopes of -2.6 and -3.7 for dust <~3 mm and larger, respectively. Observation also suggests possible temporal and spatial variations in the color and polarimetry of the ejecta and tail. Further analysis is needed to fully understand additional features, including the circular features and arc-like features in the ejecta, the double-tail, and the dust cloud to the south of the main tail observed ~4 months after the impact.

Two groups of m-sized boulders are observed in the ejecta. One group is embedded in the ejecta cone, with diameters of a few meters and moving at 20 – 30 m/s, primarily clustered in two directions. Another group is observed to distribute around the asteroid in the deep exposure acquired two months after the impact, indicating slow speeds of a few m/s and diameters of 3 – 7 m. The detection of m-sized boulders suggests a broad size distribution of the dust in the ejecta.

The morphological characteristics of the ejecta from Dimorphos differ significantly from those observed from Comet 9P/Tempel 1 during the Deep Impact mission, likely due to the different volatile compositions, dust sizes, and surface and subsurface conditions of the two bodies. Notebly, the tail morphology of Dimorphos resembles those seen in certain active asteroids that are believed to result from impulsive dust release triggered by impacts, rotational instability, or binary interactions, This similarity clearly supports the hypothesis that impacts are an important mechanism for activating asteroids.