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Dust analysis on board the Destiny^{+} mission to 3200 Phaethon

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Abstract

The Japanese Destiny^{+} spacecraft will be launched to the active asteroid 3200 Phaethon in 2022. Among the proposed core payload is an in-situ dust instrument based on the Cassini Cosmic Dust Analyzer. We use the ESA Interplanetary Meteoroid Engineering Model (IMEM), developed by Dikarev et al. (2005a,b), to study detection conditions and fluences of interplanetary and interstellar dust with a dust analyzer on board Destiny^{+}.

1. The Destiny^{+} Mission

The Japanese Space Exploration Agency (JAXA) recently approved a new space mission, Destiny^{+}. The mission target is the active asteroid 3200 Phaethon which is an Apollo asteroid with an orbital period of about 1.4 years. The launch is presently planned for 2022, and the spacecraft will be orbiting the Sun between 0.8 and 1.2 AU (Fig. 1), with a Phaethon flyby planned for 2025 (Sarli et al., 2016).

Among the proposed core payload is an in-situ dust instrument based on the Cosmic Dust Analyzer on board the Saturn orbiting Cassini spacecraft (Srama et al., 2004). The Destiny^{+} dust analyzer will be an impact ionization time-of-flight mass spectrometer capable of analyzing sub-micron and micron sized dust grains with a mass resolution of $m/\Delta m \approx 150$. In addition to the investigation of Phaethon and its dust environment, the mission goals comprise the analysis of interplanetary and interstellar dust grains with the Destiny^{+} dust analyzer.

2. Dust Simulations

We study the detection conditions for interplanetary and interstellar dust particles during the spacecraft's interplanetary cruise. Our particular goal is to predict dust impact speeds, impact directions and fluences.

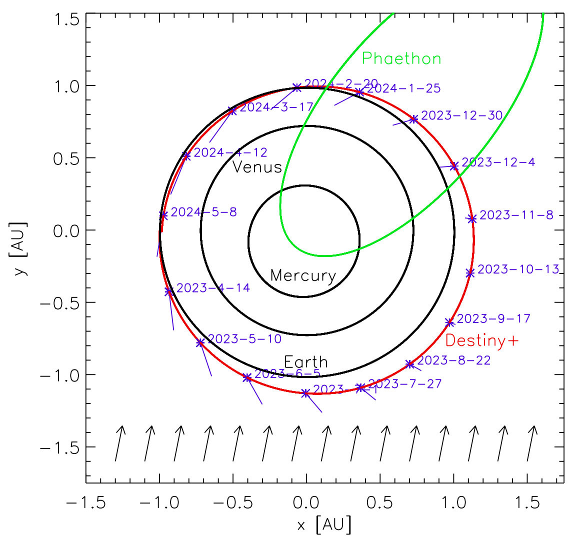

Figure 1: Trajectories of Destiny^{+} (*red*, only the initial 1.3 years of the heliocentric trajectory are shown for clarity) and 3200 Phaethon (*green*). The interstellar dust flow in the heliocentric system is indicated by black arrows, and the ram direction of interstellar grains is shown by blue bars, bar lengths being proportional to the grain impact speed. Times are indicated at the Destiny^{+} trajectory.

We perform our analysis with the ESA Interplanetary Meteoroid Engineering Model (IMEM) developed by Dikarev et al. (2005a,b). The model is based on infrared observations of the zodiacal cloud by the Cosmic Background Explorer (COBE) DIRBE instrument, in-situ flux measurements by the dust detectors on board the Galileo and Ulysses spacecraft, and the crater size distributions on lunar rock samples retrieved by the Apollo missions. It simulates the dynamics of cometary and asteroidal dust in the planetary system. Interstellar dust is described in a simplified form: A mono-directional stream of grains with an assumed ratio of gravitational to radiation pressure force $\beta = 1$ is parameterised by its apex direction and heliocentric flow speed of $26\,\mathrm{km\,s^{-1}}$ (Landgraf, 2000), as well as the mass distribution of the constituent particles.

3. Results and Conclusions

The initial 1.3 years of the Destiny$^+$ interplanetary trajectory are shown in Figure 1. In spring 2023, and during all later times when the spacecraft traverses the same region of the inner solar system, Destiny$^+$ moves approximately antiparallel to the interstellar dust flow. At this time impact speeds of interstellar grains are high, reaching a maximum of $55\,\mathrm{km\,s^{-1}}$. The spacecraft motion around the Sun leads to strong variations of the impact angle and impact speed with time.

In the simulations, the approach direction of the interstellar grains forms a narrow peak (at azimuth $165°$ and declination $90°$ in Figure 2), while the interplanetary dust has a much wider distribution of impact angles (*top panel*). In the time interval shown, the impact speed of the interstellar grains exceeds the speed of the interplanetary impactors by far (*bottom panel*). Thus, the impact speed is a crucial parameter to identify interstellar impactors.

Our simulations show that for Destiny$^+$ the best time period to detect interstellar grains and to separate them from the interplanetary particle background is the spatial region traversed by the Earth in winter and spring when impact speeds of interstellar grains are high. In the region traversed by the Earth in summer and autumn, impact speeds of interstellar grains are much lower and these grains can hardly be identified. We also present dust fluxes and fluences for the Destiny$^+$ dust analyzer for a total mission duration of 1200 days. Future work will focus on a more realistic model for the dynamics of the interstellar grains to predict more reliable impact speeds and directions than provided by the IMEM interstellar dust module.

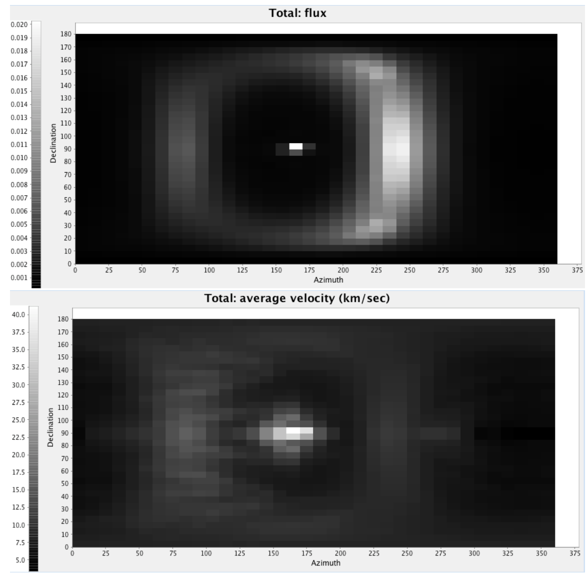

Figure 2: IMEM sky maps showing the distribution of particle fluxes (*top panel*) and impact speeds (*bottom panel*) of interplanetary and interstellar grains in a spacecraft-fixed coordinate system for the time period 1 to 15 April 2023. Azimuth $180°$ points toward the direction of the spacecraft speed vector and declination $90°$ is close to the ecliptic plane.

Acknowledgements

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