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Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond (4)

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INTERACTION OF INTERPLANETARY DUST WITH A LASER-DRIVEN LIGHTSAIL DURING ACCELERATION

Abstract

The interaction of the main laser of a laser-driven lightsail with the dust grains of the interplanetary media is considered. The impact of dust grains on the lightsail during the acceleration phase is of concern due to the impact event affecting the low laser absorptivity of the sail, which could result in significant deposition of laser energy into the sail and subsequent destruction of the sail. Thus, the potential of the drive laser to significantly deplete the number of dust grains in the volume to be swept by the passage of the sail would be highly advantageous and warrants study. Use of a 100-GW-class laser to clear the sail flight path prior to acceleration is found to be impractical due to the large volume that would need to be cleared. The laser light diffracted around the sail and transmitted through the sail, on the other hand, can have a significant interaction with dust grains that are immediately ahead of the sail, particularly for the case of a dielectric sail that would be significantly transparent in order to maximize acceleration. The laser profiled is modeled as an ideal Airy pattern and the diffraction of the beam profile around the sail is handled using standard analytical treatments; extension of the technique to more realistic profiles that would be synthesized from a phased-array beamer is straightforward. The laser—dust particle interaction is modelled via accepted models for continuous laser-driven ablation, and the subsequent grain motion is treated using rocket-equation-like models of ablation-driven blow-off. Both idealized (spherical) and more realistic (aggregated) grain morphologies are considered. Monte Carlo simulations using state-of-the-art models for size and mass distributions of interplanetary dust grains provide guidance in determining if the drive laser can also have a significantly beneficial effect on the number of dust grains that will strike the sail during the acceleration phase. The design trade-offs between using more reflective vs. more transmissive lightsail material can be explored in relation to the dust interaction problem.