The Prediction of Particle Bombardment Interaction Physics due to Ions, Electrons and Dust in the Interstellar Medium on a Gram-Scale Interstellar Probe

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Abstract

The Breakthrough Starshot initiative proposes to send a Gram-scale laser driven spacecraft to the Alpha Centauri system in a 20 years mission travelling at $v \sim 0.2c$. One of the challenges of this mission as the spacecraft moves through the interstellar medium is the presence of dust and gas (mostly hydrogen). The dust has a typical matter-density of $2.57 \times 10^{-27} gcm^{-3}$ with typical particle mass being $3 \times 10^{-13} g$ although some of the largest particles may be $5 \times 10^{-9} g$ in mass. These dust particle will deposit $\sim 10^{12} - 10^{16} MeV$ onto the spacecraft with an energy flux of order $\sim 0.3 Js^{-1} m^{-2}$. We consider the erosion of the spacecraft frontal area due to dust and also heating effects as well as charged particle penetration due to ions and electrons for which at the Project Starshot cruise speeds charged particle collisions can result in a collision energy as high as $\sim 75MeV$ for the non-metals (hydrogen and helium) and as high as $\sim 300MeV$ for the metals (Carbon and Oxygen). In this paper, we attempt to characterize the likely environment for the starshot mission and estimate the particle bombardment shielding requirements in terms of mass and thickness of material. We also examine the penetration effects and stopping power of the various bombarding particles and consider the implications for the success of the starshot mission. Current analysis estimates that the likely erosion rates are of order $\sim 10^{-10} - 10^{-11} gs^{-1}$ and that the frontal area temperatures are in the range $\sim 200 - 400K$ depending on the ratio of frontal area to radiating area in the range $Ao/A \sim 1 - 100$. For an assumed shielding material with atomic number range $3 - 13$ (Lithium to Aluminum), this would suggest a shielding thickness of $\sim 1 - 3mm$, with a mass in the range $0.01 - 0.2g$; depending on the material choice. The aim of this work is to keep the shielding mass down to less than 5% of the total Gram-scale vehicle mass. The work presented highlights the close coupling in the Project Starshot spacecraft design between the chosen vehicle geometry and the particle bombardment requirements. This paper is submitted for the day 2 session Sails and Beams.

Keywords: Interstellar Medium, Particle Bombardment, Project Starshot

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