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Monte Carlo Simulation of Shock-Environment Interactions: Insights into Spectral Breakpoints in SEP Events

The conventional Diffusive Shock Acceleration (DSA) model assumes that a single shock generates solar energetic particles (SEPs) with a single power-law energy spectrum. However, interplanetary shocks undergo complex interactions with diverse media during their propagation from the Sun to planets, including planetary magnetospheres. For instance, the interaction between shock fronts and dense solar wind plasma near planetary obstacles can trigger magnetic reconnection and rapid turbulence diffusion at shock-medium interfaces, which may impede seed particle acceleration. This study employs Monte Carlo simulations to investigate the interaction between an interplanetary shock and the Martian bow shock during the February 15, 2022 SEP event. The bow shock, formed by solar wind deflection at Mars' induced magnetosphere, exhibits a thickness of ˜17 km and stands ˜90,000 km upstream from the planet. Shock converging effects arise when the propagating shock compresses and heats the pre-existing solar wind plasma, altering local magnetic field configurations and wave turbulence patterns. Such interactions modify particle acceleration efficiency, potentially creating a characteristic spectral breakpoint energy E_{break} in SEP spectra. These findings advance our understanding of particle acceleration in multi-shock systems and provide a framework for interpreting future PSP and Solar Orbiter observations. The methodology also applies to other shock interaction scenarios, such as corotating interaction regions (CIRs) and comet bow shocks.

Collaboration(s)

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