Electron injection threshold and acceleration processes at Earth's foreshock transients

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Abstract

Collisionless shock waves are prevalent in various plasma environments throughout the Universe, from supernova remnants and planetary atmospheres to coronal mass ejections and laboratory settings. These shocks are among nature's most potent particle accelerators and are crucial for understanding cosmic rays, particularly ultra-relativistic particles.

In this study, we integrate in-situ data from NASA's Magnetospheric Multiscale (MMS) and Acceleration, Reconnection, Turbulence, and Electrodynamics of Moon's Interaction (ARTEMIS) missions to introduce a novel model of reinforced shock acceleration for electrons. Our findings reveal a suprathermal electron injection threshold specific to Earth's planetary environment, employing a multiscale framework that systematically accelerates suprathermal electrons to relativistic energies.

By merging theoretical advancements in astrophysical plasmas and shock physics, we demonstrate how foreshock transient phenomena, a suprathermal seed population, and wave-particle interactions collectively address the persistent electron injection problem. Additionally, we explore the broader applicability of our model to other planetary environments within our solar system and beyond, extending to stellar and interstellar contexts.