

The Role of Shock-Generated Transients in Particle Acceleration at Planetary Bow Shocks

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Abstract

Collisionless shock waves are ubiquitous and efficient particle accelerators in astrophysical plasmas, from supernova remnants to planetary bow shocks, and are fundamental to understanding the origin of cosmic rays. This study integrates high-resolution in-situ data from NASA's Magnetospheric Multiscale (MMS); Cluster and ARTEMIS missions highlight how particle acceleration occurs across shocks and how it changes during variable driving conditions and the presence of transient phenomena.

Focusing on Earth's bow shock, our analysis identifies how a multiscale framework can systematically accelerate a suprathermal seed population to relativistic energies. We investigate the crucial role of foreshock transient phenomena, particularly hot flow anomalies, in this process and elaborate on their direct relationship with the formation of high-speed magnetosheath jets. We also discuss the subsequent effects of these disturbances on the dayside magnetospheric system, linking solar wind phenomena directly to internal magnetospheric dynamics.

Furthermore, we discuss how our investigation generalizes to other planets. This establishes a broader framework for understanding particle acceleration and magnetospheric impact to planetary environments in our system.