Collisionless Shocks in the Heliosphere: Transient Processes and Particle Energization

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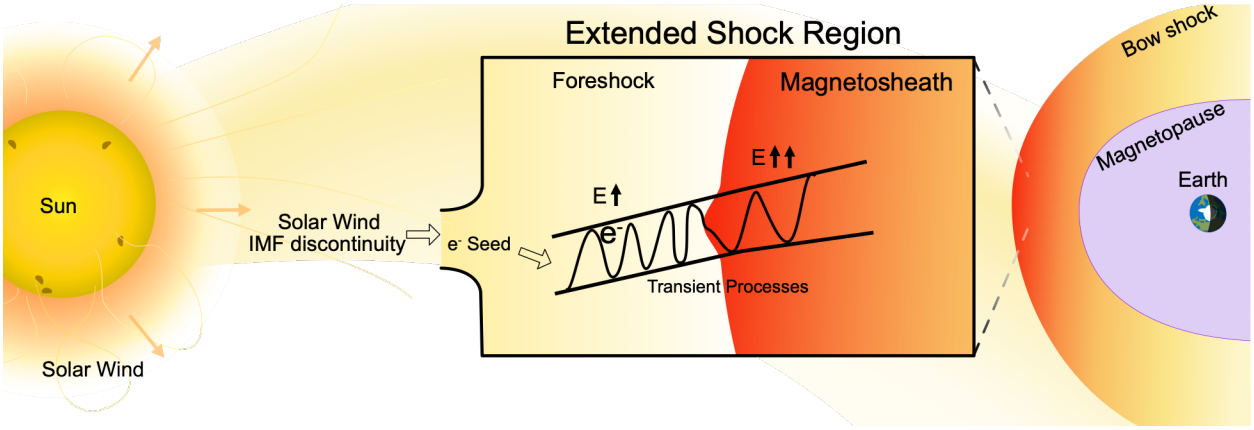

Collisionless shocks are the primary sites for particle acceleration across the Universe, yet the specific mechanisms that bridge the gap from thermal seeds to relativistic cosmic rays remain a subject of active research. This seminar explores the evolving paradigm of shock acceleration, at planetary bow shocks, moving beyond steady-state models to highlight the critical role of upstream transient processes.

Focusing primarily on Earth's bow shock using high-resolution data from NASA's MMS and THEMIS, alongside ESA's Cluster missions, we discuss how the dynamic region upstream of a shock (the foreshock) is not merely a precursor zone but an extended environment of elevated particle acceleration. By examining the formation and evolution of foreshock transient structures, we demonstrate how these local disturbances fundamentally alter the broader shock environment. These transients facilitate a reinforced shock acceleration process, injecting suprathermal particles and providing the confinement necessary for energization through a multiscale process that includes adiabatic and non-adiabatic acceleration processes as they transition downstream. Finally, we scale these physical insights to larger systems, using recent observations from Jupiter's bow shock via NASA's Juno mission, to demonstrate that these processes are a universal feature of planetary environments. By bridging these *in-situ* observations with broader scaling laws, we show how localized transient dynamics can be potentially used to constrain the maximum limits of particle acceleration at shocks.