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Energetic Particle Acceleration and Modulation in the Heliosphere: The Role of ICMEs and Planetary Magnetospheres

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Interplanetary Coronal Mass Ejections (ICMEs) are critical drivers of energetic particle dynamics across the heliosphere, influencing both solar energetic particle (SEP) acceleration at ICME-driven shocks and the modulation of galactic cosmic rays (GCRs), resulting in observable Forbush decreases. The interaction of these heliospheric transients with planetary magnetospheres provides a unique laboratory for studying acceleration and transport processes in complex plasma environments.
Saturn's magnetosphere, while internally dynamic, allows for the penetration of heliospheric energetic particles such as SEPs and GCRs. Observations from the Cassini mission have shown that these particles can access the outer and middle magnetosphere, enabling indirect solar wind monitoring and revealing ICME-induced variations such as Forbush decreases and SEP-driven transient radiation belts.
In contrast, Jupiter's much stronger and rapidly rotating magnetosphere presents a fundamentally different scenario. External solar particles - particularly SEPs - encounter significant barriers to entry due to the planet's intense magnetic field and dense, internally sourced plasma environment, limiting direct SEP penetration into the inner magnetosphere. Instead, Jupiter sustains its own high-efficiency particle acceleration processes, including wave–particle interactions and rotationally driven transport. These mechanisms energize particles to MeV and, in some cases, relativistic energies, producing radiation belts and current systems that effectively mask or override signatures of heliospheric transients.
By examining different aspects of these planetary magnetospheres, we gain deeper insights into the physics of energetic particle acceleration and transport.
These findings have implications not only for understanding space plasma dynamics but also for analogous processes in astrophysical and laboratory settings.

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