

Probing Plasma Complexity: The Emergent Stability of Particle Diffusion during Forbush Decreases

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Despite significant advancements in modeling solar modulation, the comprehension of the diffusion parameters of galactic cosmic rays in the heliosphere remains challenging due to model parameter degeneracies and limited 3D in situ observations. In the attempt to contribute to the modeling of the diffusion term, here we explore the possibility of using Forbush Decreases (FDs) as natural probes to study particle transport at intermediate rigidities. In this study, we analyze a sample of FD events using high-precision daily GCR measurements from AMS-02 and the HelMod-4/CUDA numerical framework. Our results indicate that while CMEs enhance magnetic turbulence—drastically reducing the diffusion coefficient and causing the observed GCR depletion—the rigidity dependence of the diffusion tensor remains consistent throughout both the perturbed and recovery phases with values observed during quiet periods. This emergent stability suggests that the fundamental scattering mechanisms are preserved even during extreme solar transients, providing critical insights into the universality of transport regimes and the modeling of plasma complexity. Building on this proof of concept, future extensive analyses of the full FD catalog will leverage the new high-performance COSMICA and SDEGnO frameworks. This transition will enable a massive exploration of the parameter space and its inherent degeneracies, providing deeper insights into the fundamental mechanisms of solar modulation.