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Turbulent Reacceleration of Streaming Cosmic Rays: Fluid Simulations

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We present MHD+CR simulations probing reacceleration of pre-existing cosmic rays by long-wavelength, subsonic, compressive turbulence. With purely diffusive transport, we recover the scaling relations of Ptuskin 1988, where the reacceleration time reaches a minimum at the "sweet spot"diffusion coefficient of the sound speed times the outer turbulence scale, $D_{\rm crit} \sim c_s L$. For GeV energy cosmic rays, however, where self-confinement and streaming transport likely dominate, reacceleration rates are highly suppressed at low plasma β; collisionless energy loss $\propto v_A \cdot \nabla P_{CR}$ largely offsets energy gain, even when additional diffusion at the "sweet spot"value of $D_{\rm crit}$ is included. At higher plasma β (when diffusive transport dominates), which may be appropriate in galaxy halo environments, the energy gain time is again quite short (as low as a few eddy turnover times).

This in-situ cosmic ray production, especially if coupled with reacceleration by large-scale shocks, can increase non-thermal pressure support in the circumgalactic medium, as required to explain COS-Halos absorption line measurements, and could leave an imprint in diffuse gamma-ray emission. In low-β environments like the interstellar medium, reacceleration of GeV-energy cosmic rays can likely be ignored. This may alleviate tension between current cosmic ray reacceleration models and recent observations by Voyager 1 and AMS-02 that favor pure diffusion / convection models.

Keywords

Confinement, reacceleration, turbulence, particle acceleration

Collaboration

other Collaboration

Subcategory

Theoretical Results

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