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Estimating radial diffusion using a hybrid-Vlasov simulation

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Radial diffusion coefficients quantify non-adiabatic transport of energetic particles by electromagnetic field fluctuations in planetary radiation belts. Theoretically, radial diffusion occurs for an ensemble of particles that experience irreversible violation of their third adiabatic invariant, which is equivalent to a change in their Roederer L^* parameter. Thus, the Roederer L^* coordinate is the fundamental quantity from which radial diffusion coefficients can be computed. We present a methodology to calculate the Lagrangian derivative of L^* from global magnetospheric simulations, and test it with an application to Vlasiator, a hybrid-Vlasov model of near-Earth space. We use a Hamiltonian formalism for particles confined to closed drift shells with conserved first and second adiabatic invariants to compute changes in the guiding center drift paths from background electric and magnetic field fluctuations. Performing this calculation for different

energies allows the rate of change of L^* to be evaluated for different populations travelling along the same guiding center drift path without the need to inject and trace test particles. We investigate the feasibility of this methodology by computing the time evolution of L^* for an equatorial ultrarelativistic electron population travelling along four guiding center drift paths in the outer radiation belt of a five minute portion of a Vlasiator simulation. Due to the short time scale and geometry of the test run, low amplitude Pc3 fluctuations are the primary driver of radial diffusion, which results in preliminary estimates for the radial diffusion coefficients that are two to six orders of magnitude below those corresponding to more active magnetospheric conditions with Pc5 fluctuations as the primary driver. However, our results show that an alternative methodology to compute detailed radial diffusion transport is now available and could form the basis for comparison studies between numerical and observational measurements of radial transport in the Earth's radiation belts.

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