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Electron Diffusion in Self-Consistent Numerical Experiments: Incoherent Broadband Waves

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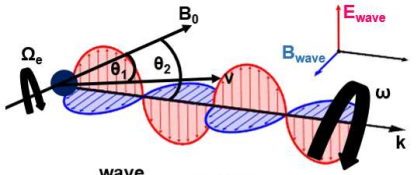
Introduction

Diffusion codes in Radiation Belt models (RBMs) are based on the quasilinear theory (QLT) of wave-particle interactions. Whistler-mode waves are included in RBMs, and contribute to local acceleration and loss of electrons. However, whistler-mode waves are unlikely to always satisfy the formal requirements of QLT. We use particle-in-cell (PIC) simulations to test this hypothesis.[1]

Wave-particle interactions



wave particle

$$\omega - k_{||} v_{||} = n\Omega_e$$

★ Resonance condition ★

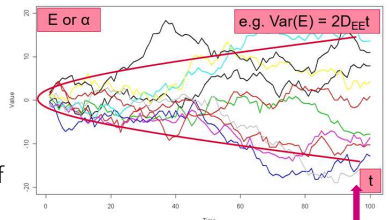
Quasilinear diffusion

Assumptions: a background B_0 with 'waves on top' such that:

- For every particle, there is a wave that is resonant
- Wave spectrum is broadband
- Wave phases are random
- Wave amplitudes are small
- *(Wave spectrum is time-independent: extra condition used in radiation belts)*

Construct direct diffusion coefficients (if possible) from tracer statistics, evolving plasma through T=300t_{ce}:

- **QLT is based on Einsteinian diffusion**, e.g. variance of E, α behave as if under Brownian motion.
- **We test this assumption**, cf. similar works in [4,5] and [6,7] for test-particle and PIC respectively.

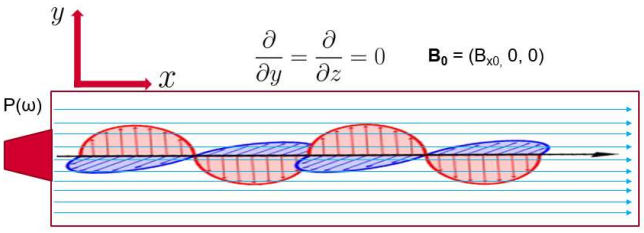


★ Classical diffusion ★

$$\frac{\partial f}{\partial t} = \sum_{ij} \frac{\partial}{\partial J_i}\left[D_{ij}\frac{\partial f}{\partial J_j}\right] \qquad D_{EE}(E,\alpha) = \frac{\langle(\Delta E)^2\rangle}{\Delta t}$$

PIC simulations with EPOCH

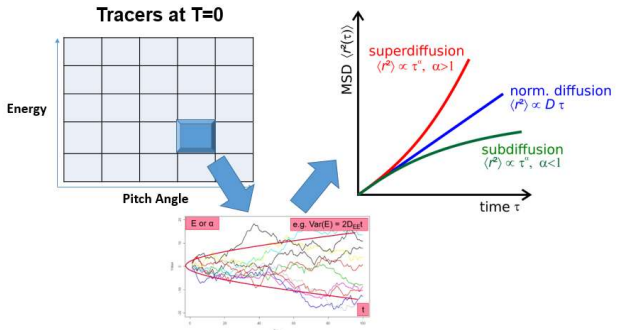
- **Open-source**, explicit, relativistic and parallelised[2]
- **Demonstrated utility** for the study of whistler-mode waves[3]



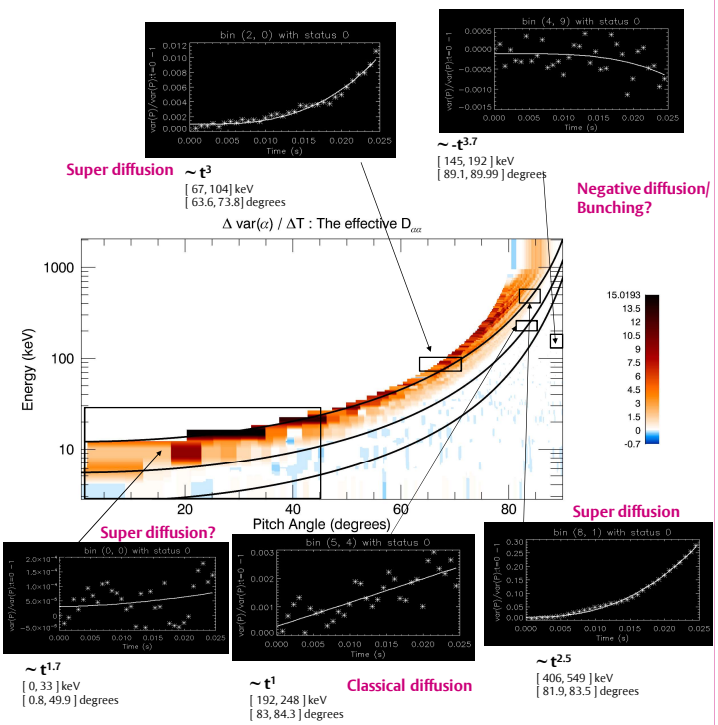
$$\frac{\partial}{\partial y} = \frac{\partial}{\partial z} = 0 \qquad \mathbf{B_0} = (B_{x0}, 0, 0)$$

Analysis of the diffusion

- **We bin the initial tracer population in (Energy, Pitch Angle) phase-space**
- **Then track the subsequent evolution of the particles in that bin**



How did the variance in each bin change?



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