# Stochastic models of phase space diffusion via wave-particle interaction with parallel propagating electromagnetic waves

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Particle diffusion due to electromagnetic waves is one of fundamental processes in various phenome in space plasms such as electron acceleration in the outer radiation belt [e.g., Saito et al, JGR, 2016], astrophysical shock [e.g., Yamazaki, JHEA, 2015], and solar wind [e.g., Seough et al, APJ, 2015]. Although quasi-linear theories are widely used as a standard theory of particle scattering, nonlinear wave-particle interactions such as particle trapping also affect particle diffusions in the presence of finite amplitude waves. Saito et al [JGR, 2016] demonstrated that nonlinearity of whistler chorus waves plays a significant role in electron diffusion though nonlinear wave-particle interactions.

In Saito et al [JGR, 2016], the artificial randomization of gyrophases (phase breaking) is incorporated to discuss suppression of coherent wave-particle interactions. Remark that such a randomization corresponds to a noise term in equations of motion of each particles. In this sense, phase breaking causes not only the suppression of coherent processes but also diffusions in phase space. In the present study, we discuss the generalization of phase breaking. It is shown that particle diffusion depends on probability density functions of noises and their parameters. Noise terms in equations of the pitch angle are also necessary to describe diffusion in phase space. Treatment of phase breaking as a stochastic differential equation is also discussed.

Keywords: particle diffusion, wave-particle interactions, stochastic model, whistler waves, magnetohydrodynamic waves