Nonlinear dynamics of resonant particles interacting with coherent waves and comparison with quasi-linear theory

*Miwa Tobita[1], Yoshiharu Omura[1]

1. Research Institute for Sustainable Humanosphere, Kyoto University

We perform test particle simulations of charged particles in an external constant electric field and electrostatic wave fields. We solve equations of motion, which take the same form as the pendulum equation, and we study nonlinear dynamics of particles with different values of inhomogeneity factor S defined as a ratio of the wave amplitude to the background electrostatic field. The target of the present study is to understand nonlinear dynamics of resonant particles interacting with coherent waves in space plasmas. Electromagnetic waves such as whistler-mode chorus, hiss emissions, and electromagnetic ion cyclotron (EMIC) waves in the inner magnetosphere contain structures of coherent waves with various discrete frequencies. Their interaction with resonant particles can be approximated by the nonlinear pendulum equation, or the equations of motion for a charged particle in a one-dimensional electrostatic wave potential. Conventionally, particle scattering and energization are studied as particle diffusion by incoherent waves without any background field causing adiabatic variation of the drift velocity. However, this model, called quasi-linear diffusion model, cannot explain “super diffusion”, referring to MeV energization and precipitation of particles in a few minutes, found in observations of chorus, hiss, and EMIC waves. To describe the super diffusion with the simplified electrostatic model, we introduce the external constant field, which corresponds to an inhomogeneous magnetic field causing adiabatic motion such as mirror motion. All particles are accelerated uniformly and constantly as an adiabatic motion, and they are dramatically heated by scattering and/or nonlinear trapping through resonant interaction with the waves. The present simulation model demonstrates the super diffusion due to coherent waves and the external field.

Keywords: wave-particle interaction, nonlinear wave trapping, particle acceleration

