Test Particle Simulations on Acceleration of Relativistic Electrons by Coherent Whistler-Mode Waves in the Earth's Radiation Belt

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It is well known that in a recovery phase of geomagnetic storm, the flux of relativistic electrons (~MeV) in the Earth's outer radiation belt can increase to beyond pre-storm levels. They cause serious damage to electrical devices in satellites. Nowadays, space weather forecasting, in which predicting and preventing the damage from high energy particles, is increasing in importance as space activity becomes more developed.

By means of test particle simulations, we have found a very efficient acceleration process of relativistic electrons in the outer radiation belt. This is due to particular nonlinear resonant trapping by coherent whistler-mode waves in a dipole magnetic field. During the acceleration process, wave trapped electrons change the direction of motion to the same direction of wave propagation, and we call the process relativistic turning acceleration (RTA).

On the assumption that wave frequency is constant, with a sufficiently long whistler-mode chorus wave packet of the order of a few hundred milliseconds, electrons of a few hundred keV are accelerated to the range of a few MeV through a single resonant trapping process. The necessary wave amplitude is a few hundred pT. The minimum energy of electrons accelerated by RTA, and the maximum energy attained by it are derived analytically and verified by the test particle simulations.

In reality, however, chorus emission is a whistler-mode wave packet which has a finite length and has a frequency which increases in time. We found that electrons are also accelerated in a few hundred keV by RTA when two chorus emissions with time dependent frequency are generated at the equator and propagate to the north and south. We also studied the evolution of energy distribution functions by Green's function approach. We found that a delta function in energy space evolves into a distribution with high-energy tail, which can be the mechanism for the generation of relativistic electron fluxes in the outer radiation belt.

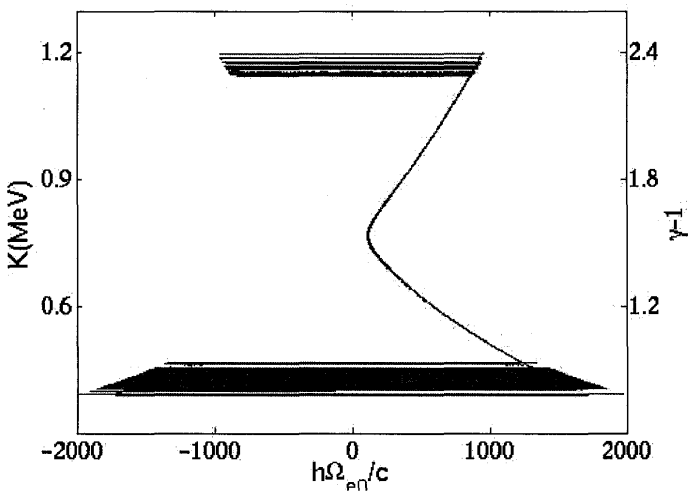

Fig1. Trajectory showing energy increase. Horizontal axis means the distance h Ω_{e0}/c and vertical axis is electron kinetic energy (MeV). 21 out of 90 electrons are trapped and accelerated.