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Acceleration of relativistic electrons in the outer radiation belt through the wave particle interaction with electromagnetic wave

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Acceleration of electrons up to relativistic energies through the resonant wave particle interaction have been studied by using a newly-developed numerical simulation scheme.

This simulation scheme, where cold component of electron is treated as a fluid while hot component of electron is treated kinetically including relativistic effects, has developed to overcome the difficulty due to the significant difference of Larmor radii between thermal electrons and relativistic electrons in outer radiation belt. We have applied our simulation code to the study of storm-time energizing process of relativistic electrons by whistler mode waves.

In the outer radiation belt, the flux of relativistic electrons once decreases in the main phase of geomagnetic storms and increases again in the recovery phase [e.g. Friedel et al., 2002]. The acceleration process of such relativistic electrons has been studied in details for the case of the stochastic acceleration with enhanced whistler mode waves. Although studies of stochastic acceleration process has been achieved to explain energizing of relativistic electrons by using Fokker-Planck formulation [Summers and Ma 2000; Miyoshi et al., 2002], energy diffusion coefficients which deeply affect on the time scale of energizing, are still remained the consideration of nonlinearity.

As for the first step, we have discussed the effect of the characteristics of wave spectrum on electron energizing process by comparing the case of monochromatic wave (Case 1, frequency with 0.5 fc) and the case of waves with finite wave band (Case 2, 0.3 to 0.6 fc) using one dimensional simulation code. We choose system length as 400km and time scale as 80 msec for numerical experiment, and plasma environment is assumed to be fp/fc=1, where fp and fc is plasma frequency and cyclotron frequency of electron, respectively. Initial velocity distribution of hot electrons is given to 0.5 C centered maxwelian, corresponding to nearly 100 keV electrons (C is light speed). Simulation results show that maximum variation of hot electron velocity is 0.004 C in Case 1 and 0.002 C in Case 2. Although maximum variation of resonant electron velocity in Case 1 is larger than that of Case 2, there appear difference in time variation of configuration of velocity distribution.

Acceleration process of relativistic electrons has been discussed by several authors with importance of broad band spectrum of whistler mode waves, because the broadness of wave spectrum reveals that the resonant particles are continuously scattered in phase space up to relativistic energies by resonant wave particle interaction. Simulation results enables us to directly investigate the possibility of the effect of spectral bandwidth of whistler waves in energy diffusion coefficients.

Moreover, there still remain to be studied on candidates of other propagation modes of plasma waves for energizing process of high energy electrons because previous theoretical studies have been restricted to the case of the first order cyclotron resonance. Additionally, the settings of plasma environment of model using in regime of stochastic acceleration are constrained in low density region, it is necessary to investigate with various plasma density models in consideration of energizing process.

The purpose of present study is, then, to evaluate the accuracy of energy diffusion coefficients and the possibilities of energizing of electrons by electromagnetic waves including non-linear effect in the resonant interactions.

Numerical analysis of efficiency of nonlinearity should contribute to development of the model of storm-time energizing process of relativistic electrons.