ホイッスラーモード・コーラス放射による低ピッチ角電子の非線形ピッチ角散乱

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Nonlinear pitch angle scattering of small pitch angle electrons by whistler mode chorus emissions

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Chorus emissions are coherent whistler mode waves with frequency sweeping observed in the inner magnetosphere. Previous ground-based and satellite observation have indicated that there is strong relation between chorus emissions and pulsating auroral precipitation. Conventionally, it has been considered that electrons in the energy range from a few keV to tens of keV satisfy the cyclotron resonance condition and are scattered toward the loss cone by whistler mode waves. Larger amplitude waves can more effectively scatter the pitch angle of energetic electrons toward loss cone and contribute to the enhancement of the auroral precipitation. However, the simulation result of Li et al. (2015) indicates that small pitch angle particles tend to be scattered away from the loss cone by whistler mode wave. While the nonlinear motion of resonant particles encountering a coherent wave has been studied more than 40 years (cf. Omura et al., 1991), in the derivation of the equations, previous studies assumed small wave amplitude compared to the ambient magnetic field B_0 (Dysthe, 1971) and large pitch angle of energetic electrons (Nunn, 1974).

In this study, we derive the equations without both of the assumptions, and theoretically evaluate the additional term related to the Lorentz force caused by the wave magnetic field and the parallel component of the velocity of a resonant particle. Furthermore, we carry out a test particle simulation and reproduce that the additional term plays a role of the pitch angle scattering away from the loss cone. In the simulation results of parallel propagating coherent waves with constant frequency, diffusion-like scattering of resonant electrons is observed in the case of waves with weak amplitude (0.1 % of B_0). On the contrary, all of resonant electrons are scattered in the pitch angle away from the loss cone in the case of waves with larger amplitude (more than 0.5 % of B_0). We also carry out simulations for the case of waves with frequency sweeping and find that particles near the loss cone are more effectively scattered away from the loss cone by the wave with large amplitude (more than 0.7 % of B_0). Additionally, we calculate the motion of the large number of electrons and evaluate the variation of pitch angle distribution. As a result, the wave intensity and the number of particles in the loss cone are not necessarily proportional. These results suggest that the relation between chorus wave intensity and the flux of auroral electron precipitation is not straightforward and should be investigated by considering the nonlinear effects.