Acceleration of the relativistic electrons induced by low energy electrons - Resonant interaction process

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On the rebuilding process of the earth's outer radiation belt during the recovery phase of a geomagnetic storm, the resonant scattering process via whistler-mode waves has been recognized as the strong candidate mechanism for the acceleration of relativistic electrons. Theoretical analyses suggested that the range of the frequency of whistler-mode waves is suitable for the resonant interaction with MeV electrons in the inner magnetosphere, and observational evidences revealed the relationship between the intensification of the flux of MeV electrons and the enhancement of whistler-mode waves during a storm-time. The sequence of the acceleration process of relativistic electrons are briefly explained by the scenario as following: (1) whistler-mode waves are excited by several tens keV electrons which are transferred from the plasmasheet by the enhanced convection and the radial diffusion process; (2) high energy electrons are scattered by the enhanced whistler-mode waves and EMIC waves, while EMIC waves mainly contribute to the pitch angle scattering rather than the energy change; (3) during the resonant scattering process, a part of high energy electron reaches relativistic energies. As proposed by several workers, since the high energy electrons and the keV electrons are connected each other by resonance ellipses of whistler-mode wave, the energy source required for the acceleration of relativistic electrons should be provided by the kev electrons. It is remained to be considered that the quantitative estimation of the energy transfer process between relativistic electrons and keV electrons.

In the present study, we performed the numerical experiment of the energy transfer process between the relativistic electrons and the keV energy electrons through the cyclotron resonant interaction with whistler-mode waves. Our simulation scheme is based on the model which treats cold electrons as a fluid and hot electrons as particles, focusing with their larmor radii. In our model, whistler-mode waves are self-consistently excited by the keV electrons due to the temperature anisotropy. To sustain the instability caused by the temperature anisotropy, the velocities of the keV electrons are initialized periodically. The condition and initial parameters used in our simulation are the following: The one-dimensional simulation system along the field-aligned direction is employed with the periodic boundary condition; plasma parameter (fp/fc) of the background cold electrons is equal to 2.0; the temperature anisotropy Vt,perp/Vt,parallel = 4.0 is provided to the keV energy electrons, and 1 MeV centered shifted-maxwellian is assumed as the energy distribution of the relativistic electrons, respectively.

In the early stage of the experiment, whistler-mode waves with narrow band spectrum were excited, while the growth of the fastest growing mode was consistent with the growth rate predicted by the linear theory. During the amplitude of the whistler-mode wave reached tens mV/m, relativistic electrons subsequently trapped by the whistler-mode wave. The position of trapped electrons in the phase space was localized around the resonance ellipse of the whistler-mode wave, and they converged along the diffusion curve toward the resonance ellipse corresponds to the frequency of the fastest growing mode.

These results show that the resonant scattering process was adequately simulated in our experiment, and the quantitative estimation of the energy transfer between relativistic electrons and keV electrons is discussed.