Study of the Pitch Angle Scattering of Small Pitch Angle Electrons by Coherent Whistler-Mode Waves

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Previous studies indicated that whistler mode chorus emissions scatter the pitch angle of energetic electrons, contributing diffuse and pulsating aurora, and reported a high correlation of observed wave amplitude to both auroral luminosity [Nishimura et al, 2010] and electron flux in loss-cone [Kasahara et al, 2018]. However, detailed processes scattering electrons into the loss cone are still unclear. Conventionally, the pitch angle scattering of energetic electrons has been considered as a diffusion process based on the quasi-linear theory. On the other hand, recently Kitahara and Katoh (2019) theoretically and numerically revealed that coherent whistler-mode waves effectively trap small pitch angle electrons and change their pitch angle away from the loss cone. Further investigation for the detailed process of the pitch angle scattering by chorus emissions has been required.

In the present study, we have updated the test particle code of Kitahara and Katoh (2019) in order to treat a large number of electrons at a massively parallelized supercomputer system. By using the developed code, we compute the motion of energetic electrons moving along a field line under the presence of a packet of monochromatic whistler-mode waves generated at the magnetic equator. We assume both the wave amplitude and frequency of whistler-mode waves by referring to the typical parameters observed in the magnetosphere; we assume the wave frequency 0.3 times of the electron gyrofrequency at the magnetic equator, and change the wave amplitude from 0.01 to 0.1% of the background magnetic field intensity at the equator. We also change the duration of the wave packet as well as the amplitude modulation in time, corresponding to the sub-packet structure of the waveform of chorus elements; the duration time of main wave packet and sub-packet at the magnetic equator are assumed to be 97.2 ms and 14.6 ms, respectively. Our simulation results show that most of resonant electrons are trapped by the waves and scattered in the pitch angle range away from the loss cone in the case of waves without amplitude modulation, as reported by Kitahara and Katoh (2019). When the amplitude modulation is present, we find electrons scattered into the loss cone and evaluate the ratio of the number of electrons inside/outside the loss cone quantitatively.

Furthermore, since previous studies revealed that whistler mode waves propagating toward the equator also contribute nonlinear trapping of resonant electrons (e.g., Omura and Summers, 2006), we consider the effects of the location of whistler-mode wave's source region by changing the wave generation region in the simulation system from the magnetic equator to the off-equatorial region. Simulations with initial conditions based on the observed pitch angle distribution in the inner magnetosphere are also performed to compare with the Arase satellite observation. Based on the simulation results, we discuss the favorable condition and roles of nonlinear trapping in the pitch angle scattering of energetic electrons.

Keywords: Pitch angle scattering, whistler-mode wave, pulsating aurora

