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Deformation of electron distributions due to Landau trapping by the whistler-mode wave

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Wave-particle interactions are known to play an important role in regulating energetic electron distributions in the Earth's inner magnetosphere. In particular, whistler-mode waves can efficiently modulate the electron distributions by cyclotron and Landau resonant interactions. By a two-dimensional (2-D) electron magnetohydrodynamics model, we simulate a whistler wave in the dipole geomagnetic field and show that a parallel whistler wave becomes gradually oblique during its propagation from the magnetic equator to high latitudes. Furthermore, a test-particle simulation shows that such a whistler wave can trap and accelerate electrons from the lower latitudes to higher latitudes by nonlinear Landau trapping, which leads to the rapid formation of electron butterfly distributions at tens of keV. Previous studies suggested that nonlinear cyclotron trapping can cause electron butterfly distributions at tens of keV observed in the Earth's magnetosphere. Our study provides a new potential formation mechanism of electron butterfly distributions in the Earth's magnetosphere.

Figure 1 displays the propagation characteristics of the whistler wave packet emitting from the magnetic equator in the simulation.

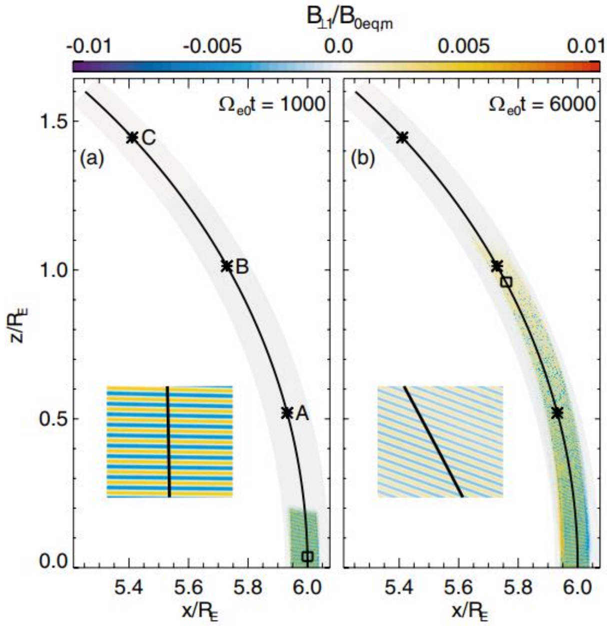

Figure. 1. (a, b) The spatial profiles of perpendicular (to the simulation plane) magnetic fluctuations in the Cartesian coordinates (x, z) at $\Omega_{e0}t$=1200 and 6000. Three asterisks marked by “A”, “B” and “C” locate at the magnetic latitudes $\lambda = 5°$, $10°$ and $15°$.

Figure 2 demonstrates the effects of the whistler wave on the electron pitch angle distributions at higher latitudes. A whistler wave causes distinct flux increases of 10s keV electrons at large pitch angles to form electron butterfly distributions.

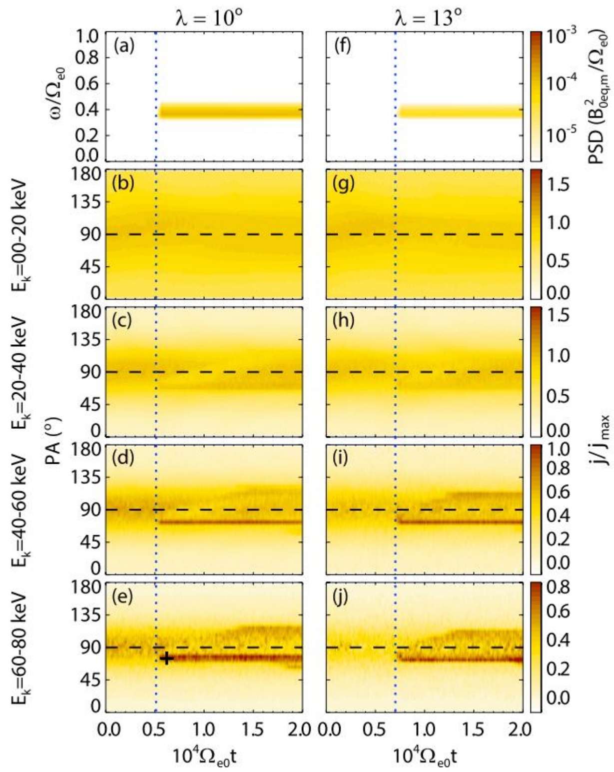

Figure. 2. (a, b) The power spectral density (PSD) of the wave magnetic field at the magnetic latitudes $\lambda = 10°$ and $13°$ on the field line $L = 6$. (b-e, g-j) The time evolutions of electron pitch angle (PA) distributions at different energy channels at $\lambda = 10°$ and $13°$, respectively. And j_{max} is the maximum value of the local electron differential flux j.

References

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