# Multiple manifestations of whistler-mode wave-particle interactions in Earth's Outer Radiation Belt

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The Earth's Outer Radiation Belt is a highly-variable region of high-energy electrons that forms a torus spanning 2.5-7 Earth radii from our planet. In this region, the number flux of electrons of energies between 100keV to a few MeV can vary by an order of magnitude in a matter of hours. It is now widely understood that a large contribution to the variability in the Outer Radiation Belt is wave-particle interactions in the collisionless natural plasma environment of the Earth's magnetosphere. Many different wave modes, across a large frequency range, are important for the dynamics of the Outer Radiation Belt, but here we focus on the physics of the whistler-mode interaction with electrons in all its different manifestations.

The whistler-mode wave is a right-hand polarised electromagnetic wave mode with frequency between the proton and electron gyrofrequency that displays different characteristics in different parts of the magnetosphere. Evidence of temperature anisotropy and beam-driven instabilities both exist, but some magnetospheric whistler-mode waves are generated in the terrestrial atmosphere during lightning strikes (true "whistlers"), and some from man-made transmitters on Earth's surface. Additionally there is evidence that waves are naturally generated in one part of the magnetosphere and propagate through the inner magnetosphere to other locations where the wave-particle interaction changes due to different ambient plasma conditions [e.g. *Bortnik et al., 2008*].

We use linear and quasilinear theory and fully nonlinear numerical experiments to study both acceleration and loss of electrons in the Outer Radiation Belt of Earth as a result of all the different manifestations of whistler-mode waves. We compare and contrast the observational evidence for different types of whistler-mode waves in the magnetosphere and discuss the theoretical approaches suitable to study the wave-particle interactions that result.

Bortnik, J., R. M. Thorne and N. P. Meredith (2008), The Unexpected origin of plasmaspheric hiss from discrete chorus emissions, Nature, 452, 62-66, doi:10.1038/nature06741