Effects of kappa distributions on radiation belt dynamics

D. Summers

Memorial University of Newfoundland, Canada

Chorus waves play an important role in controlling electron radiation belt dynamics. Stochastic acceleration due to electron gyroresonance with whistler mode chorus can generate relativistic electrons in the Earths outer radiation belt. Gyroresonant interaction with whistler mode chorus can also cause electron losses from the inner magnetosphere via pitch angle scattering loss to the atmosphere.

The generation process of whistler mode chorus comprises a linear growth phase followed by a nonlinear growth phase. Linear wave growth is described by cyclotron resonance (Kennel-Petschek) theory whereby waves are excited by injected anisotropic electrons of tens-of-keV energy. A nonlinear cyclotron resonance theory has recently been developed to describe the nonlinear growth phase of whistler mode waves. Nonlinear phase trapping, the generation of an electromagnetic hole in phase space, and the associated nonlinear resonant current are found to be instrumental in the nonlinear wave growth process. Special forms of nonlinear phase trapping by coherent whistler mode waves provide the basis for efficient electron energization mechanisms known as relativistic turning acceleration and ultrarelativistic acceleration.

Here, we further examine the theory of linear and nonlinear growth of whistler mode chorus waves. We adopt the bi-Maxwellian, bi-Lorentzian (kappa), and Dory-Guest-Harris loss cone particle distributions. We generalize to an arbitrary energetic electron distribution the chorus equations, which are nonlinear ordinary differential equations that describe the generation of a whistler mode chorus element at the equator, and we calculate the associated threshold wave amplitude for sustained nonlinear growth. We solve the chorus equations for the wave magnetic field amplitude and frequency, and hence obtain solutions for the nonlinear growth rates. For each distribution, we construct complete time profiles for the wave magnetic field amplitude that smoothly match at the interface of the linear and nonlinear growth phases. We investigate the role of kappa distributions in the nonlinear wave growth process.

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