Analytical Treatment of Nonlinear Electron Behavior in Resonance With Large Amplitude Whistler Waves

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Cyclotron-resonant interactions with whistler mode chorus waves are believed to be crucial in determining the behavior of radiation belt electrons. These interactions also underlie the generation and evolution of the whistler waves, but for the purpose of modeling the radiation belts, which form the high energy (MeV) tail of the particle distribution, it is useful to consider the electrons as test particles, and to impose a model of the waves as generated by a lower energy (keV, ring current) population.

Broadband quasi-linear theory has been traditionally used to model these interactions, but is inappropriate for interactions with quasi-monochromatic waves. Such interactions are coherent, and while small amplitudes also result in diffusion, large amplitudes lead to qualitatively different behavior. Analytical treatments of such interactions have also been developed, with various degrees of approximation, and yield phase bunching and phase trapping, with deterministic (rather than effectively random) changes in energy and pitch angle. Because the repeated interactions give directed, rather than random, walks, the cumulative effects on energy and pitch angle are much larger than for diffusion. Thus the long-term predictions are highly sensitive to the details of the underlying wave models.

Corresponding transport (advection) coefficients are being developed for use in modified versions of existing large scale simulations, namely the 3D drift-averaged radiation belt code DILBERT and the 4D bounce-averaged Ring current-Atmosphere interactions Model (RAM). The RAM code can supply realistic, time-dependent initial and boundary conditions for the radiation belt population. It can also evaluate wave growth rates from the modeled ring current population, using linear theory, which will be augmented by new, high resolution wave measurements from the THEMIS and RBSP spacecraft. Thus there is real hope of dynamically modeling wave-driven radiation belt behavior, even under highly disturbed conditions.