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# Resonant Interactions Between Discrete Coherent Whistler-mode Waves and Energetic Electrons

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Cyclotron resonant interactions between whistler-mode waves and energetic electrons have long been known to be important in the dynamics of the radiation belts, both from the point of view of amplification of waves and the pitch angle scattering and precipitation loss of the energetic particles. In most cases, the interactions have been treated using linear or diffusion analyses, with the inherent assumption that the waves involved are broadband and incoherent. However, in actual fact many of the waves that permeate the radiation belts can be highly coherent, and discrete, with particular frequency-time signatures, such as lightning generated whistlers, emissions triggered by externally injected signals, and spontaneously generated chorus emissions. Cyclotron resonant interactions involving such waves are fundamentally different than those involving broadband incoherent waves, since the energetic electrons can be phase trapped in the wave potential well, and follow specific paths in velocity space, with their pitch angles (for example) changing over many degrees in one interaction, rather than following a random-walk involving many encounters, with each encounter amounting to an only small variation in particle energy or pitch angle.

There is clear evidence from controlled wave-injection experiments that the coherence of the waves involved in such interactions is the crucial ingredient that leads to nonlinear exponential wave growth, which is suppressed if the waves are incoherent. It is thus evident that the high amplitudes of whistler-mode wave energy that permeate the radiation belts must have initially originated in coherent form, as is also evident from the extremely coherent and discrete nature of chorus emissions, especially when they are observed in and near their source regions. In this talk, we present a review and comparative perspective of nonlinear versus linear and coherent versus incoherent wave-particle interactions, specifically those involving discrete whistler-mode waves in the inner and outer radiation belts.