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Observational and numerical studies of frequency chirping rate of chorus waves

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Extended Abstract

The underlying physical mechanism of the nonlinear frequency chirping of whistler mode chorus waves has been investigated for more than fifty years; nevertheless, a consensus has yet to be reached. Various theories have proposed different ways of calculating chorus wave frequency chirping rate. Some theoretical models (for example, the Helliwell model) give a chirping rate that depends on the background plasma parameters only. On the other hand, more recent models, based on nonlinear wave particle interactions and phase space dynamics of energetic electrons demonstrate that the frequency chirping rate is also related to the wave amplitude at generation. In this work, we will present some of our recent observational studies using NASA Van Allen Probes about the frequency chirping rate of both rising and falling tone chorus waves. The dependence on both background plasma parameters and wave amplitude will be analyzed and discussed. Comparison of the chorus frequency sweep rate with different previously published theoretical models will be given. We will also present numerical simulation studies using a hybrid particle-in-cell simulation code DAWN, demonstrating the amplitude modulation of chorus waves that has also been found in observation. With phase space diagnostics, we suggest that the amplitude modulation could be naturally explained by the periodically varying energy of phase space trapped resonant particles and the self-consistent requirement that the total energy should be conserved. This leads to that the amplitude modulation period should be on the same order as the particle phase space trapping period. A few possible ways of connecting this numerical result with observations will be discussed.