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2D Simulations of Magnetospheric Chorus Wave Generation with TRISTAN-MP PIC Code

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Magnetospheric chorus waves are one of the most intense wave phenomena in the Earth's inner magnetosphere. They play important role in particle dynamics in the outer radiation belt, causing particle energization and precipitation via resonant wave-particle interaction. These waves are observed as series of quasi-coherent wave-packets with rising [1] or, sometimes, falling frequency [2]. Chorus waves are generated in the equatorial region as a result of whistler instability of anisotropic electron distribution. Their frequency chirping is generally assumed to be a non-linear phenomenon associated with formation of a non-linear current and corresponding electromagnetic holes or hills [3]. Due to non-linear nature of these waves, the opportunities of their theoretical study are rather limited, and self-consistent numerical simulations are required.
The majority of numerical simulations of chorus waves, as well as the theory [3], are one-dimensional, thus taking into account only the waves which propagate strictly parallel to background magnetic field. At the same time, oblique chorus waves are observed in the magnetosphere, and theoretical estimations show that obliquity might lead to essential effects like generation of the gap at half cyclotron frequency [3], or generation of falling-tone elements due to competition between Landau and first cyclotron resonances [4]. Two-dimensional (2D) codes allow the generation of oblique waves, and are required to study, when and if the effects related to wave obliquity are important.
In this report, we present the results of simulations of whistler instability and chorus generation with the 2D full Particle-in-Cell code TRISTAN-MP. This code models self-consistent dynamics of three particle populations: ions, cold electrons with isotropic Maxwellian distribution, and hot electrons initially having anisotropic relativistic Maxwell-Juttner distribution. We investigated the dependence of chorus generation process on the distribution anisotropy, hot-to-cold density ratio, and background magnetic field inhomogeneity. Our results are consistent with the one-dimensional simulations and theory. According to the theory, there exists a wave amplitude threshold below which no non-linear particle trapping takes place, hence, the chorus waves are not generated. Higher inhomogeneity leads to higher threshold amplitude, thus, it suppresses the generation of chorus waves. These properties of the chorus wave generation are reproduced in our 2D simulations.

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