GC2024-STP009

Interaction of Relativistic Electrons with Electromagnetic Ion-Cyclotron Wave Packets of a Finite Length

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The interaction of relativistic electrons with electromagnetic ion cyclotron (EMIC) waves can scatter such electrons into the ionosphere. Estimates of resonant energies for this interaction give values about 1 MeV and higher. Recently, there were observations of precipitating electrons with energies of hundreds keV associated with EMIC waves [1]. This precipitation can be caused by the interaction of relativistic electrons with EMIC wave packets of finite length [1,2].

We consider such an interaction in this paper. We study the dependence of the interaction characteristics on the packet length and amplitude both analytically (for linear regime) and numerically (by test particle method in both linear and nonlinear regimes). We also calculate (numerically) precipitation fluxes, formed by this interaction.

For small wave amplitudes, corresponding to linear regime, we obtain analytical estimates for the variance of the equatorial pitch angle of electrons. For wave packets located not far from the geomagnetic equator analytical solutions agree with numerical results.

We show that widening of the wave number spectra caused by short packet length expands the interaction region into the low energies that are outside the resonant range for the central packet wave number. This effect takes place both in the linear regime and in the force bunching regime caused by direct influence of the Lorentz force on the electron phase.

The regions of nonlinear trapping and phase bunching do not expand towards lower energies, i.e. these regimes are possible only for energies corresponding to the resonant interaction with the central wave-packet component.

For EMIC wave packet amplitudes corresponding to nonlinear interaction, there is a range of energies for which the precipitating flux is equal to the value for the limiting case of strong diffusion, and even slightly exceeds it. The maximum value of the ratio of the fluxes of precipitating and trapped particles is approximately 1 and (at sufficiently high wave amplitudes) does not depend on the wave packet amplitude or length. The minimum energy for which significant precipitation occurs decreases with decreasing packet length from the minimum resonant value to approximately its half.

Thus, interaction with a short packet of EMIC waves can lead to significant (i.e., corresponding to strong pitch-angle diffusion) precipitation of particles with energies noticeably lower than the resonant energy for the carrier packet wave number. For the Earth's magnetosphere, these energies amount to a few hundred keV.

Work of V.S.Grach funded by Russian Science Foundation, Grant 19-72-10111.

[1] X. An, A. Artemyev, V. Angelopoulos, et al. Phys. Rev. Lett. V. 129 (2022). 135101.

[2] V.S. Grach, A.G. Demekhov. Plasma Physics Reports V. 49 (2023). 901.