Relativistic electron interaction with upper hybrid waves as a driver of precipitation bursts

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Summary

Observations of particle precipitation into the Earth's atmosphere performed on low-altitude satellites have excited substantial interest in relativistic electron precipitation bursts from the outer zone of the radiation belt (see, for instance, [1-2] and references therein). As underlying mechanism of such bursts, we suggest particle scattering into the loss cone due to higher-order cyclotron resonance interaction between relativistic electrons and intense narrow-band upper hybrid waves [3], which are frequently observed outside the plasmapause [4]. We discuss pro and con of this mechanism in comparison with previously considered scattering of relativistic electrons by whistler-mode chorus [5]. The case of a single wave and the case of a wide wavenumber spectrum are considered, and approximate expressions for the relativistic particle diffusion coefficients in phase space are calculated for conditions of an inhomogeneous plasma. While the case of a single wave is similar to proton scattering by a lower hybrid resonance wave [6], the calculations for a wide spectrum in an inhomogeneous plasma are presented for the first time. It is found that relativistic electrons have a preference over lower energy electrons from the viewpoint of the number of cyclotron resonances that a particle crosses during each bounce period. This factor competes with the larger inertia of more energetic particles that overtakes for very large energy, leading to a peak electron scattering in the range of near-relativistic to relativistic energies. Due to the predominantly longitudinal direction of the upper hybrid wave group velocity, the resonant wave-particle interaction can take place over many electron bounce periods, which facilitates the particle scattering into the loss cone. The developed theory accounts for two main features of the relativistic electron precipitation bursts, namely, a strong energy dependence in the electron precipitation process, and the small-scale burst structure, which is primarily attributed to the localization and strong inhomogeneity of the growth region of the upper hybrid modes responsible for the scattering. The existence of intrinsic temporal structure of the precipitation on time scales comparable to the bounce period is also consistent with the theory due to the high efficiency of the scattering process.

References

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