THE EVOLUTION OF ELECTRON HOLES AND GENERATION OF ELECTROSTATIC WHISTLER WAVES

Georgios Vetoulis and Meers Oppenheim

Center for Space Physics, Boston U., 725 Comm. Ave., Boston, MA 02215 U.S.A., Email meerso@bu.edu

Abstract

Recently, bipolar electric field structures have been identified in the auroral acceleration region, the magnetotail and the foreshock region by many spacecraft. Strong evidence from these observations indicates that these structures result from electron phase-space holes, regions of depleted electron density commonly generated during the nonlinear stage of the two-stream instability. Many questions about their formation, evolution, and the role that holes play in space physics remain unanswered. This paper describes the long-term evolution of holes in 2-D and 3-D, massively-parallel, PIC simulations, discusses their decay while emitting electrostatic waves, and their possible role in generating VLF saucers observed in the highly magnetized downward current region of the aurora.

In 2-D and 3-D simulations of the time evolution of highly magnetized electron holes, the holes persist for hundreds of plasma periods and then decay while emitting electrostatic whistler waves governed by the dispersion relation $\omega^2 = \omega_p^2 \cos^2\theta$ where θ is the angle between the wavevector $\mathbf{k}$ and $\mathbf{B_0}$ while ω_p is the plasma frequency [3, 1, 2, 4, 6, 5]. An electron trapped in a hole can resonate with a wave of frequency ω, if $\omega\tau_b(\epsilon) = 2\pi n$ where n is a positive integer and τ_b is the electron's bounce period (a function of its energy, ϵ). We show that if the trapped electron distribution f_0 satisfies $\partial_\epsilon f_0/\partial_\epsilon \tau_b > 0$ at the resonant energies, wave excitation occurs [7]. This theory explains many aspects of the waves observed in simulations. and may also account for observations of VLF saucers (electrostatic waves propagating obliquely to the geomagnetic field) as well as of the characteristics of the holes in the auroral ionosphere.

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