Geophysical Research Abstracts, Vol. 9, 00998, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-00998

Electron phase-space holes in a two-dimensional plasma

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The parallel component of the electric field ($E_{||}$) in electron phase-space holes exhibits bipolar structures along the magnetic field direction, and recent satellite observations found that their perpendicular electric field component ($E_{\perp}$) is unipolar. In this letter, we performed two-dimensional (2D) electrostatic particle simulations to investigate the nonlinear evolution of electron beams instability. The results show that electron holes can be formed during its nonlinear evolution. Inside the holes, a series of islands with alternate positive and negative $E_{\perp}$ can be formed in the direction perpendicular to the background magnetic field and are unipolar in the direction parallel to the background magnetic field. These structures appear to be intermittent since they persist over hundreds to thousands of the plasma periods but disappear at much later time due to the excitation of electrostatic whistler waves. These structures can explain the observed unipolar structures of $E_{\perp}$ along the parallel slicing of the background magnetic field. The influence of the amplitude of the background magnetic field is also considered.