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New Features of Electron Phase Space Holes Observed by the THEMIS Mission

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Observations of large-amplitude (>100 mV/m) electron phase-space holes by the THEMIS satellites indicate several new features including a magnetic perturbation parallel to the ambient magnetic field (B). We interpret this signal as currents from the perpendicular magnetic field. Under this interpretation, parallel magnetic perturbation is directly proportional to the potential of the electron phase-space hole. Many of the structures also have magnetic signature (roughly 0.1 pT) perpendicular to B, which we interpret as due to high speeds (>10,000 km/s) along B. The high speeds suggest that the electron holes are generated by an electron two-stream interaction, but a Buneman instability cannot be ruled out. In addition, we show that electron holes can be physically large in the direction along B (50-100 Debye lengths) and, when combined with the large electric field signal, have a signification potential well associated with them, on the order of a kV. This large potential suggests strong, nonlinear behavior nearby, such as double layers or magnetic reconnection. Another rare property is also observed. A set of the high-speed electron holes indicate a "bullet" shape in which the perpendicular scale appears to be only a few electron gyroradii. The majority, however, have a extended perpendicular direction. The THEMIS "burst" (high time resolution) waveforms are selected on board by the electric field amplitude, so we study a subset of these structures with high amplitudes. Almost all occasions of electron phase space holes observed by the THEMIS satellites during a three month magnetotail phase were found at the boundary between the dense plasma sheet and the tenuous lobe plasma. Almost all events were at periods of increased auroral activity so they seem to be associated with reconfiguration of the magnetotail due to substorms. These results suggest that electron phase-space holes are an indicator of the large-scale behavior of the plasma sheet.