Electron Sloshing associated with Inertial Alfvén Waves

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Auroral electron acceleration is a significant and unsolved problem in space physics. The processes responsible for producing accelerated electrons that precipitate from the magnetosphere onto the ionosphere are not fully understood. For more than three decades, particle interactions with Alfvén waves have been proposed as a likely means for accelerating electrons and generating auroras. Under the assumptions of ideal MHD, Alfvén waves do not produce an electric field parallel to the mean magnetic field $\mathbf{B_0}$ and therefore cause no parallel electron motion. However, when the electron thermal speed v_{te} is less than the Alfvén speed v_A, and when the Alfvén wave structure across $\mathbf{B_0}$ is comparable to the electron skin depth $\delta_e = c/\omega_{pe}$, the Alfvén wave transitions to the inertial Alfvén wave. Unlike ideal MHD Alfvén waves, inertial Alfvén waves do have a parallel electric field capable of modifying parallel electron motion. Using a model that calculates particle distributions, Kletzing (J. Geophys. Res., 99, No. A6, 11095-11103, 1994) showed that the parallel electric field of inertial Alfvén waves can accelerate electrons to velocities near twice the Alfvén speed through a nonlinear resonant process analogous to single bounce Fermi acceleration. These results also showed a linear oscillation, or *sloshing*, of the entire electron distribution at the Alfvén wave frequency. Though qualitatively distinct, the two responses are theoretically related. The linear electron oscillations are necessary for the nonlinear solution that includes resonant electron acceleration.

Due to the limitations of spacecraft conjunction studies and other multi-spacecraft approaches, it is unlikely that it will ever be possible, through spacecraft observations alone, to confirm definitively the proposed electron acceleration mechanism by making simultaneous measurements of both the accelerated electrons and the Alfvén wave responsible for the acceleration. Consequently, laboratory experiments may be the most direct way to test theories of electron acceleration by Alfvén waves. In this experiment, performed using the Large Plasma Device (LaPD) at UCLA, the suprathermal tails of the reduced electron distribution function parallel to $\mathbf{B_0}$ are measured with high precision as Alfvén waves simultaneously propagate through the plasma. Electron distribution measurements are performed with whistler-mode waves as part of an electron cyclotron absorption diagnostic (D.J. Thuecks *et. al*, Rev. Sci. Instrum., 83, 083503, 2012). Measurements have isolated sloshing of the electron distribution at the Alfvén wave frequency that is well-described by linear kinetic theory (J.W.R. Schroeder *et. al.*, Geophys. Res. Lett., 43, 10, 4702-4707, 2016). This result confirms basic inertial Alfvén wave behavior, and the verified linear theory will be used in the nonlinear solution for electron acceleration. No evidence for resonant electron acceleration is detected above the noise level, presumably because of the small Alfvén wave amplitudes $\delta B/B_0 \sim 10^{-5}$. Ongoing experiments are testing a new Alfvén wave antenna capable of achieving higher amplitudes.