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Energy exchange and electron dynamics in kinetic Alfvén waves

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The Alfvén wave is a ubiquitous wave mode that transports energy throughout Earth's space environment and beyond. At kinetic scales, this wave provides a critical mechanism for the transfer of energy between charged particles and electromagnetic fields. The small inter-spacecraft separation and high time resolution measurements from NASA's Magnetospheric Multiscale (MMS) mission have enabled unprecedented study of these, and other fundamental wave modes. We present observations of a monochromatic kinetic Alfvén wave packet measured in a reconnection exhaust in Earth's magnetopause boundary layer. Parallel current density and pressure-gradient-driven electric field fluctuations that were 90 degrees out of phase with one another indicated stable wave propagation and energy transport throughout the exhaust. We found a significant population of trapped electrons in the kinetic-scale magnetic mirror formed between successive wave peaks. These particles, which accounted for nearly half of the density fluctuations within the wave, provided an unexpected mechanism for maintaining quasi-neutrality. Finally, we demonstrate the capability of MMS to recover the underlying dispersion relation of broadband fluctuations observed in Earth's space environment, providing new insights into the transport of energy across boundaries in collisionless plasmas.