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Nonlinear drift-resonant interaction between particles and compressional toroidal ULF waves in a pure dipole magnetic field:Theory and Observations

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We examine the drift-resonant particle dynamics for toroidal ultralow frequency (ULF) waves in a pure dipole background geomagnetic field. We confirm that the resonant condition originally believed to apply only for poloidal ULF waves, $m\omega_d = \omega$, also applies for compressional toroidal waves. The predicted phase relationships have been confirmed from Van Allen Probes observations. Their good agreement provides the first observational evidence for the drift resonance condition controlled by the compressional toroidal ULF wave. Moreover, we extend the drift resonance theory into a nonlinear regime. The resulting particle motion can be described by a modified pendulum equation with solutions depending on the wave number m. For high-m toroidal waves, the resonant islands become asymmetric to perturb the particle trajectories within each potential well and consequently increase the trapping widths in both energy and L-shell.

We further carry out test-particle simulations to show the evolution of electron distribution functions when they interact with either toroidal or poloidal waves. These findings demonstrate that toroidal ULF waves, like their poloidal counterparts, play an important role in magnetospheric particle dynamics.

References

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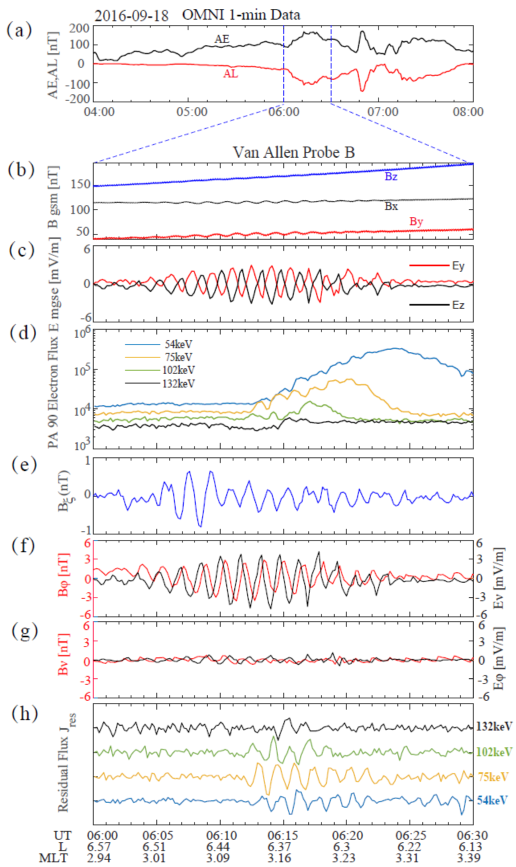

Figure 1. Overview of 18 September 2016 ULF wave-electron interaction event. (b) The magnetic field components measured in the GSM system by EMFISIS-B. (c) The electric field components measured in the mGSE system by EFW-B. (d) 90 pitch angle electron fluxes at multiple energy channels. (e) The compressional component of the magnetic field Bp in MFA coordinates. (f) The azimuthal component of the magnetic field Ba and radial component of the electric field Er in MFA coordinates. (g) The radial component of magnetic field Br and the azimuthal component of the electric field Ea in MFA coordinates. (h) The residual electron fluxes Jres obtained from (d).