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High-frequency electrostatic waves driven by electron crescents in the electron diffusion region

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Magnetic reconnection is a fundamental and universal process, which transfers energy stored in the magnetic field to kinetic energy of charged particles[1]. Magnetic reconnection powers eruptive processes in space and laboratory plasmas. Earth's magnetosphere provides a unique environment to study magnetic reconnection by analyzing in-situ spacecraft measurements. NASA's Magnetospheric Multiscale (MMS) mission[2] was designed to resolve the particles and fields at electron scales. The goal of MMS is to investigate the electron diffusion region (EDR), which is the core region of reconnection where the magnetic field lines break and reconnect. Reconnection at the dayside magnetopause is asymmetric due to the large plasma and magnetic field differences between the magnetosheath and the magnetosphere, while the reconnection in the magnetotail is mostly symmetric. Waves are suggested to generate anomalous resistivity and plasma diffusion, potentially enabling magnetic fields to break and reconnect. Various types of waves produced by reconnection have been reported outside of EDRs[3].

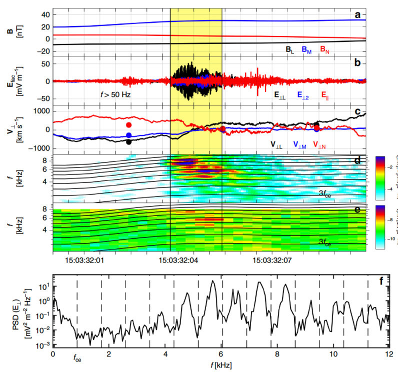

Fig. 1. Electron Bernstein waves observed by MMS[4]

The Magnetospheric Multiscale (MMS) spacecraft have encountered tens of electron diffusion regions (EDRs) of asymmetric magnetic reconnection at the Earth's magnetopause and symmetric reconnection in the magnetotail. Electron crescent-shaped distributions are extensively observed in and near the electron diffusion and drive two types of electrostatic waves. One is the electron Bernstein waves (EBWs)[4] and the other is upper-hybrid waves (UHWs)[5-7]. The EBWs are observed at the electron-scale boundary of the Hall current reversal in the outflow region of the magnetopause reconnection, while the UHWs are observed on the inflow side of EDRs of both dayside magnetopause and nightside magnetotail reconnections. The amplitudes of those high-frequency electrostatic waves are sufficiently large to thermalize and diffuse electrons. The strong interaction between the EBWs and UHWs can change the electron pressure tensor around the EDR and modify the balance of the magnetic reconnection electric field.

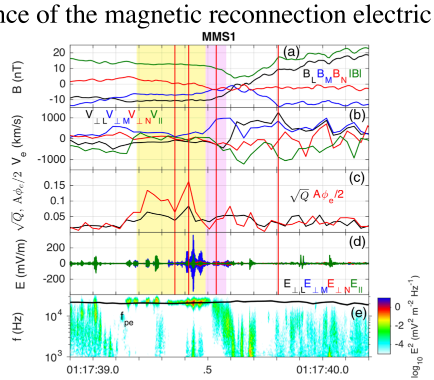

Fig. 2. Upper-hybrid waves observed by MMS[5]

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