First Electron-Scale Measurements of Magnetic Reconnection in Space

*James L Burch[1], Roy B. Torbert[1,2], Tai D. Phan[3], Li-Jen Chen[4], Thomas E Moore[5], Robert E Ergun[6], Jonathan P Eastwood[7], Daniel J Gershman[5], Matthew R Argall[2], Shan Wang[4], Michael Hesse[5], Craig J Pollock[15], Barbara L Giles[5], Rumi Nakamura[8], Barry H Mauk[9], Stephen A Fuselier[1], Christopher T Russell[10], Robert J Strangeway[10], Paul A Cassak[11], James F Drake[4], Michael A Shay[12], Yuri Khotyaintsev[13], Per-Arne Lindqvist[14], Frederick D Wilder[6], Mitsuo Oka[3], John C Dorelli[5], Jerry Goldstein[1], Daniel N Baker[6]

1.Southwest Research Institute, 2.University of New Hampshire, 3.University of California, Berkeley, 4.University of Maryland, 5.NASA, Goddard Space Flight Center, 6.University of Colorado LASP, 7.Imperial College London, 8.Space Research Institute, Austrian Academy of Sciences, 9.Johns Hopkins University Applied Physics Laboratory, 10.University of California, Los Angeles, 11.West Virginia University, 12.University of Delaware, 13.Swedish Institute of Space Physics, 14.Swedish Royal Institute of Technology, 15.Denali Scientific

Magnetic reconnection is a fundamental plasma physical process in which stored magnetic energy is explosively converted through the reconfiguration of a magnetic field into heat and kinetic energy of charged particles. Reconnection occurs in many astrophysical plasma environments as well as in laboratory plasma experiments and is responsible for solar flares and coronal mass ejections, x-ray flares in magnetars, magnetospheric storms and substorms, and sawtooth collapses in fusion devices. Although the effects of reconnection are easily observed, the electron-scale kinetic physics that allows plasmas to become demagnetized, with the resulting change in the topology of the magnetic field and the release of particle energy, has up to now eluded observation in both space and the laboratory. However, recent observations by NASA’s Magnetospheric Multiscale Mission (MMS), made with unprecedently high time resolution (100 times faster than previous missions for electrons and 30 times faster for ions), have provided the first detailed look at electron demagnetization and acceleration at sites along the sunward boundary of Earth’s magnetosphere where the interplanetary magnetic field encounters and reconnects with the terrestrial magnetic field. With these new measurements we have (1) observed the reduction of magnetic-field energy to near zero, (2) measured the reconnection electric field and the current that flows along it causing the dissipation of magnetic energy, and (3) identified the electron population that carries the current as a result of demagnetization and acceleration during their penetration of the reconnection dissipation region. The persistence of a characteristic crescent shape in the velocity-space distributions of these electrons suggests that the kinetic processes causing magnetic field line reconnection in this event were dominated by laminar electron physics rather than turbulence-induced dissipation.

Keywords: Magnetic Reconnection, Solar-Wind Magnetosphere Interactions, Charged Particle Acceleration

