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Opinion Article

NASA Initiated the Initial Phase of Magnetic Reconnection

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DESCRIPTION

Magnetic reconnection is common in laboratory, astrophysical, and space plasmas. Direct observations of pure electron outflow during this process, which alters the magnetic field's topology and releases energy into the plasma. The experimental results of a magnetic reconnection without ion flows and a pure electron outflow are presented here. By controlling the applied magnetic field in laser-produced plasma, we have constructed an experiment that magnetizes only electrons but not ions. As a result, the dynamics of electrons and ions can be distinguished. Collective Thomson scattering measurements reveal the electron Alfvénic outflow when there is no ion outflow. The plasmoid and whistler waves that were produced are shown by the measurements made by the magnetic induction probe. We simultaneously observe electron-scale magnetic reconnection's distinctive characteristics in laser-produced plasmas, including global structures, plasma parameters, the magnetic field, and waves.

Solar flares, coronal mass ejections, magnetic substorms, and disruptions of tokamak discharges in magnetically confined plasmas1,2—where plasma energy is transformed into magnetic field energy and the topology of the magnetic field is altered—all require magnetic reconnections. Electron dynamics are thought to have sparked the beginning of magnetic reconnection; The Magnetospheric Multiscale (MMS) mission, which was recently launched by NASA, has revealed the electron-scale dynamics of magnetic reconnection. The MMS spacecraft provides insight into the magnetic reconnection of the magnetic fields, the release of energy into the plasma, and other electron-scale processes aimed at resolving electron12 in the Earth's magnetosphere. These processes include the whistler wave excitation of electron temperature anisotropy and the formation of electron current sheets and outflows within an electron dissipation region [1]. In the magneto sheath, the magnetic reconnection without coupling to ions is observed due to the tiniest spatial and temporal scales of turbulent plasmas. The fundamental properties of "electron-only reconnection," which can lead to Sweet-Parker reconnection, have been examined within the confines of Magnetohydrodynamics (MHD). Numerical simulations show that electron-only reconnection begins to change into ion-coupled (MHD) reconnection at the spatial scale of, where is the ion skin depth. Electron outflows that are close to the electron Alfvén velocity can be observed [2]. Standing whistler waves or standing kinetic Alfvén waves can be used to describe these rapid magnetic reconnection processes in the presence of a guide field because MHD phenomena can be thought of as a superposition of Alfvén waves. It is difficult to link these global data on the space plasma to these local multi-point observations. Despite the presence of global images, astrophysical plasmas lack electron-scale measurements. We observe both local and global information simultaneously through controlled laboratory experiments.

Magnetic reconnections in laser-produced plasmas have been studied using the self-generated magnetic field of the Biermann battery, which is an azimuthal field around the laser spot. A solid target is irradiated by multiple laser beams, which collide anti-parallel and azimuthal magnetic fields and reconnect the plasma flow. As a direct consequence of this, we are able to exert control over the magnetization, gyroradius, and gyrofrequency parameters that are associated with the magnetic field. We have only magnetized the ions and not the electrons by employing a sufficient external magnetic field. We briefly review our previous work. In the previous study, plasma collimation was observed using interferometry in the presence of a perpendicular external magnetic field; however, plasma collimation was not observed in the absence of the magnetic field [3]. The plasma flow velocity estimates of the ion gyroradii are significantly larger than the system size, despite the fact that electrons are well magnetized [4]. Plasma flow has a dynamic pressure that is much greater than the magnetic pressure because the electron is magnetized while the ion is not. This causes charge separation across the magnetic field. This only results in electron drift. The electron moves along the distorted magnetic field rather than across it because the plasma is collimated. The collimation scenario is confirmed by particle-in-cell simulations [5]. The electron-scale magnetic reconnection is revealed by self-emission imaging of the cusp and plasmoid at electron Alfvén velocity. However, neither the distinct motion between electron and ion nor the reconnection event-relevant magnetic field was observed.

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In this paper, we present local observations of electron-scale magnetic reconnection in addition to global observations focusing on the electron dissipation region. It is clear from the measurement of the local velocity that the ion motion does not coincide with pure electron outflow. The magnetic field measurements reveal both the plasmoid-corresponding magnetic field inversion and the whistler waves associated with electron-scale dynamics. Pure electron outflow demonstrates that the magnetic energy is only released to the electrons at the beginning of the magnetic reconnection.

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