Identifying magnetic reconnection events using the FOTE method

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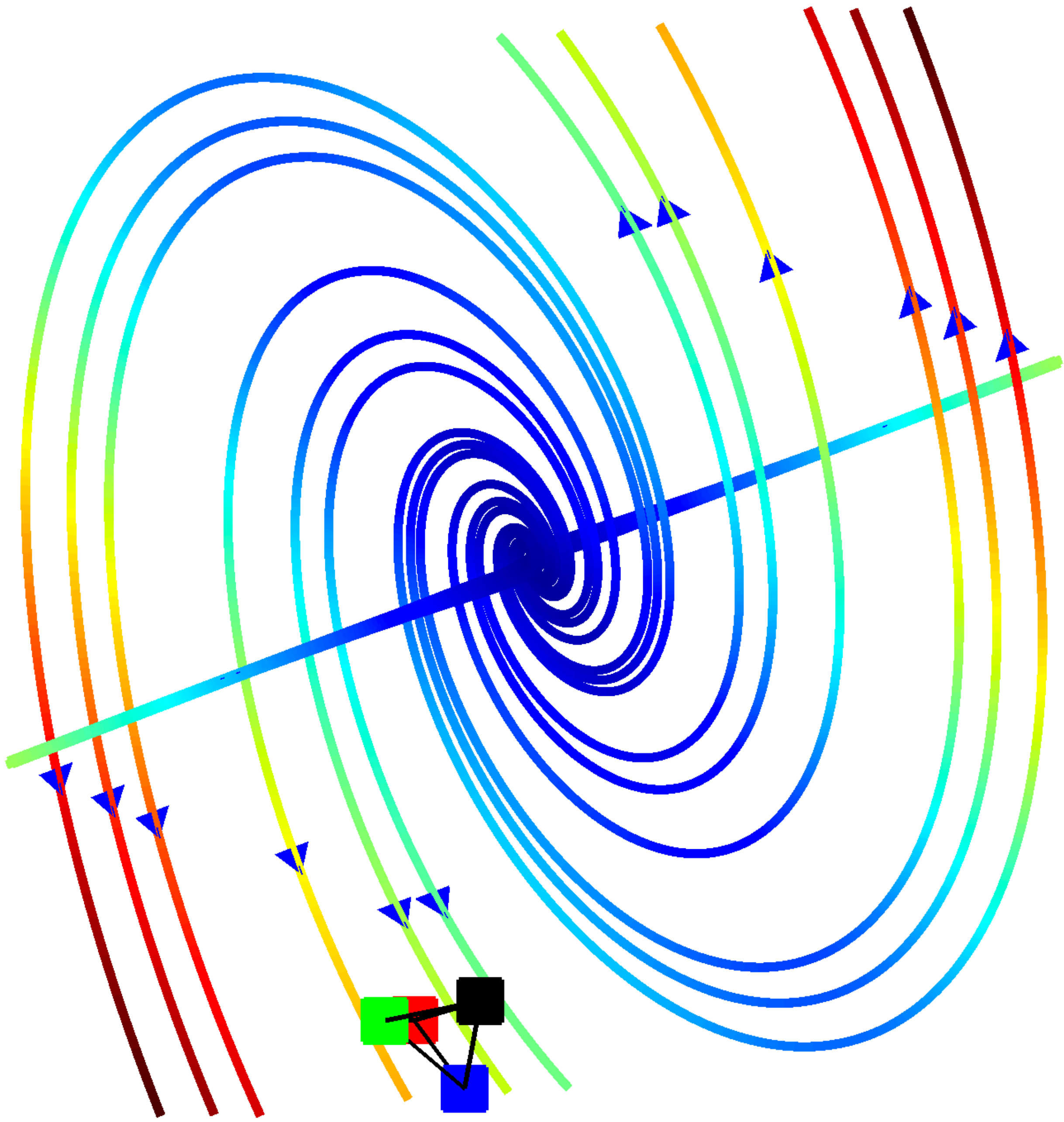
A magnetic reconnection event detected by Cluster is analyzed using three methods: Single-spacecraft Inference based on Flow-reversal Sequence (SIFS), Multi-spacecraft Inference based on Timing a Structure (MITS), and the First-Order Taylor Expansion (FOTE). Using the SIFS method, we find that the reconnection structure is an X-line; while using the MITS and FOTE methods, we find it is a magnetic island (O-line). We compare the efficiency and accuracy of these three methods, and find that the most efficient and accurate approach to identify a reconnection event is FOTE. In both the guide- and non-guide-field reconnection regimes, the FOTE method is equally applicable. This study for the first time demonstrates the capability of FOTE in identifying magnetic reconnection events; it would be useful to the forth-coming MMS mission.

Keywords: Magnetic reconnection , MMS mission, FOTE , Magnetic null , X-line , O-line



Electron acceleration at the Earth's quasi-perpendicular bow shock: MMS observation

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Electrons can be accelerated to non-thermal energies (> 1 keV) at interplanetary shocks and the Earth's bow shock. While simulation studies have proposed various mechanisms, the precise mechanism of electron acceleration remains unclear. Here we show, based on the ultra high-time resolution measurements by MMS, that electrons form a power-law energy spectrum at and around the shock ramp region. The signatures of non-thermal electrons are modulated by the periodic variations of the shock internal structure at the time scale of roughly ion gyro period. In an event of high Mach number (~11) quasi-perpendicular shock crossing (shock angle ~ 80 degrees), we found that there exists an upper energy-limit (cutoff) in the power-law spectrum at ~10 keV and that the electron gyro-radius of this energy is roughly equal to the local ion inertial length, consistent with the idea of acceleration within the narrow shock ramp region. In this presentation, we will further discuss possible mechanisms of electron acceleration by, for example, gradient B drift and stochastic processes via waves.

Keywords: particle acceleration, shock, non-thermal, MMS, electron

Excitation of whistler-mode waves in the electron scale open boundary layer generated by the dayside magnetopause reconnection

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The magnetic reconnection at the dayside magnetopause is generally because upstream physical quantities between magnetosheath and magnetosphere are quite different. Kinetic simulations of asymmetric magnetic reconnection produce an electron outflow layer mainly composed of magnetosheath electrons at the magnetosphere side of the separatrix. The simulation results suggest that this electron outflow layer corresponds to the reconnected open magnetic field closest to the magnetosphere. Based on the simulation result and data from the THEMIS probes, we show an observation of whistler mode waves in the electron outflow layer caused by asymmetric magnetic reconnection at the magnetopause. The waves propagated toward the reconnection region, and the linear growth rate of the wave was positive at the resonant velocity due to the electron temperature anisotropy. We suggest that the anisotropy can be originated from lack of the magnetospheric electrons moving anti-reconnection direction at small pitch angles since the magnetic field as a channel of the electrons connects to the magnetosheath region by the reconnection. This study quantitatively clarifies the excitation of the whistler-mode waves in the electron scale open boundary layer at the magnetopause in association with the dayside magnetopause reconnection.

Keywords: Dayside magnetopause magnetic reconnection, electron scale open boundary, Whister mode wave

Direction of motion of reconnection X-lines and O-lines at the dayside magnetopause observed by the THEMIS spacecraft

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Magnetic reconnection at the Earth’s dayside magnetopause is a fundamental mechanism that transfers mass, momentum, and energy into Earth’s magnetosphere from the solar wind. By this process, the interplanetary magnetic field (IMF) gets interconnected to the geomagnetic field lines at X-line in the magnetopause current layer. Several X-lines can exist in the magnetopause. Time-dependent magnetic reconnection in the presence of multiple X-lines generates a closed magnetic field structure with what is called O-line at the center. Some simulation studies or in-situ observations have suggested that the X-line and O-line can move. This motion is driven by magnetosheath flows or diamagnetic drift of electrons. The direction of this motion is one of the important questions of magnetic reconnection. The direction is inferred from polarity changes of oppositely directed ion jets. Ion jets flow outward from the X-line. The jets from two X-lines can converge toward the O-line between X-lines. When an X-line moves northward, a spacecraft near the X-line would observe a flow reversal from northward to southward, whereas when an O-line moves northward, a flow reversal from southward to northward would be observed near the O-line. This fact suggests that if we would like to know the direction of motion, we need to find the polarity of the flow reversal, as well as its type of structure. O-lines can be distinguished from X-lines by characteristics as described below. O-lines are characterized by an enhancement of the total pressure of order a few nPa, bipolar change of the component of the magnetic field normal to the magnetopause, and bidirectional field-aligned fluxes of heated electrons on the magnetosheath side.

We statistically investigated the direction of motion of the X-lines and O-lines observed at the dayside magnetopause, based on plasma and magnetic field data from the Time History of Events and Macroscale Interactions during Substorms (THEMIS) spacecraft. Five THEMIS spacecraft have observed Earth’s magnetosphere since launched in 2007, although THEMIS-B and -C observed the region only until 2010. We used THEMIS data taken in the magnetopause region within the magnetic local time range from 10 to 14 hours. Flow-reversal events with the flow speed exceeding 150 km/s, which is comparable to the local Alfven speed in the magnetosheath, are chosen as candidates and are used to estimate the direction of X- or O-line motion. We discuss effects of the IMF orientation and geomagnetic dipole tilt angle on the dayside magnetopause reconnection.

Keywords: magnetic reconnection, magnetopause, flow reversal

Scaling-law for early-stage development of magnetic reconnection

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A scaling-law for early-stage development of magnetic reconnection has been found from comparing two-dimensional particle simulation results of anti-parallel magnetic reconnection (asymptotic field denoted by B_0) with different current sheet thicknesses (D) and different ion-to-electron mass ratios (M). In these runs, magnetic reconnection is initiated by adding non-zero magnetic field normal to the current sheet. When the reconnected flux (in the B_0 D unit) at various times is plotted versus re-scaled reconnection electric field E_{rx} $D^{1/2}$ (E_{rx} in the V_A B_0 unit, where V_A is the relevant Alfven speed) obtained simultaneously, by which procedure a curve is obtained from each run, the curves obtained from the early development phases (reconnected flux < 2) of various runs are found to overlap among themselves. The spatial structures of some quantities around the X-lines determine the reconnection rates. Sampling the spatial profiles obtained when the same amount of magnetic flux is reconnected from different runs, we confirm that the non-dependence on M and the $D^{1/2}$-scaling of the reconnection rate are consistent with how the spatial scales vary according to M and D.

Keywords: Magnetic Reconnection

Active and non-active flow reversals observed in the magnetotail

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We have statistically examined low-frequency plasma wave activity observed in the near Earth magnetotail flow reversals. 2/3 of the flow reversals have enhanced cross-tail electron current layer and ion-electron decoupling region detected in association with the simultaneous plasma flow and magnetic field reversals (“active” X-line), while the rest events do not show visible ion-electron decoupling features (“non-active” flow reversal). The most important conclusion of the present study on the electric wave activity in the lower hybrid frequency range is that only the active X-line events are accompanied by strong wave activities. Since the region where the strong wave activities are observed overlaps well with the ion-electron decoupling region, the ion-electron decoupling process would be related to excitation mechanisms of the intense electric wave activity. It means that the electric wave power around the flow reversals is a possible indicator for the ion-electron decoupling region (possibly, the liveliness of reconnection). This new finding would be one of the clues leading to our understanding of large-scale evolution of the magnetotail reconnection site. It is hard to address the physical meaning of the differences between active and non-active flow reversals only with single spacecraft measurements. This would be a good topic to be explored using MMS.

Keywords: magnetotail, flow reversal, magnetic reconnection

Three-dimensional magnetotail reconnection: Geotail and Cluster observations

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In this study, we investigate the conditions required for reconnection at the dawn and far-dusk sides, which is significantly more rare than reconnection near midnight. We analyze more than 2 decades of Geotail and Cluster encounters with the near-Earth magnetotail reconnection site. Previous studies have suggested that reconnection onset occurs on the duskside, near midnight, and that reconnection sites may subsequently expand in the dawn-dusk direction with the cross-tail current. We find that reconnection on the duskside, near midnight can occur for comparably low and short-duration solar wind energy input. Reconnection sites on the dawn and far-dusk sides require sustained high solar wind energy input, suggesting that longer-cross-tail-length x-lines require sustained magnetotail reconnection. We also investigate the properties of the current sheet during 16 Cluster encounters with the reconnection site. We find the current sheet to be thinnest on the duskside, near midnight. Approximately where previous studies have identified the duskward edge of the reconnection site, we find the current sheet thickness to be larger than the ion inertial length, consistent with predictions from theoretical models of 3D reconnection. We compare the geomagnetic activity levels (Kp, AL, Dst) for each of the reconnection site observations. Consistent with the above solar wind activity dependence, we find that reconnection can be observed on the duskside, near-midnight, during extremely quiet times, but is only observed on the dawn and far-dusk sides during periods of highly elevated activity. This suggests that reconnection at the dawn and far dusk sides form as a result of cross-tail expansion during intervals where the total reconnection rate in the magnetotail is abnormally high. Finally, we use our work to make predictions for the upcoming MMS tail season.

Keywords: Magnetic Reconnection, Magnetotail, Magnetospheric Multiscale

Flapping current sheet motions excited by non-adiabatic ions in near-Earth magnetotail

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The current sheet is a crucial region of the magnetotail, where energy reserve and release take place. The origin of the up-down motions of the current sheet, referred to as flapping motions, is among the most fundamental issues of magnetotail dynamics. Obervational evidences suggest that the flapping motion is a kind of internal excited kink-like waves, but its particular propagating featueres such as the low phase speeds and the propagating direction from the tail center toward flanks do not match any local generation mechnisms prevrioudly established so far. Here we report observations of the current sheet flapping motions induced by non-adiabatic ions in the magentic field configurations with a finite guiding component, whose population present periodic hemispherical aymmetries.

Keywords: current sheet , flapping, non-adiabatic ions

