

First Electron-Scale Measurements of Magnetic Reconnection in Space

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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 unprecedentedly 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

Japanese Participation to MMS: Current Status and Future Plan

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MMS was successfully launched on 12 March 2015 and is continuing to produce highest quality data ever we had. Based on the results obtained by Geotail observations, Japanese researchers have been interested in the main target of MMS that is to understand the micro process of the magnetic reconnection. The same group that developed the low energy particle experiment (LEP) on Geotail has been participating to the development of one of the instruments on MMS that is FPI-DIS (Fast Plasma Investigation - Dual Ion Sensor). Design, fabrication, assembly, and the initial tests of the 16 Flight Model DIS sensors were made in Japan collaborating with U.S. and French colleagues. Currently, Japanese scientists are also participating to the initial analysis of the obtained data and evaluation of the performance of the 16 DIS sensors.

Since the time resolution of the FPI is high, the amount of the data is quite large. FPI data are delivered to Japan periodically using hard drives since it takes too long time to transfer all the data from the data center over the internet. ISAS is operating a data server for FPI data, that can be accessed by Japanese FPI team members.

The collaborative observation between MMS and Geotail is also making progress. After July 2015, the operation time of Geotail in Japan is increased in order to make collaborative observation with MMS. Since Geotail has unique orbit with apogee of 30Re and perigee of 9Re, Geotail - MMS pairs will realize multiple scale measurements of the key regions of the magnetic reconnection region. In some of the period, Geotail can be used as a solar wind monitor, that is closer to the magnetosphere than solar wind monitor at L1 point.

Since many Japanese researchers have great interest in the night side phenomena in the Earth's magnetotail, we are placing high expectations on the MMS Phase2 data that will be obtained in the near future. The time resolution of the Geotail low energy particle observation was 12 seconds. Therefore it was difficult to see the detailed structure of the the Earth's magnetotail. Although the sensitivity of the FPI sensors are not enough high for tenuous plasma measurements in the magnetotail, they can make observation much faster than 12sec. FPI- DIS will be able to measure low energy ions with more than an order higher time resolution than Geotail-LEP even taking into account the sensitivity. Many new discoveries are expected to be made also in the Earth's magnetotail in the near future.

Keywords: magnetic reconnection, satellite observation, plasma measurement

Geospace Exploration Project ERG: Contribution to Heliosphere/Geospace (H/GSO) system observatory

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The ERG (Exploration of energization and Radiation in Geospace) is Japanese geospace exploration project. The project focuses on the geospace dynamics and accelerations of radiation belt electrons in the context of the cross-energy coupling via wave-particle interactions. The project consists of the satellite observation team, the ground-based network observation team, and integrated-data analysis/simulation team. The ERG satellite will be launched in FY2016. Comprehensive instruments for plasma/particles, and eld/waves are installed in the ERG satellite to understand the cross-energy coupling system. In the ERG project, several ground-network teams join; magnetometer networks, radar networks, optical imager networks, etc, which provide a global view of geospace and complementary observation with the ERG satellite observation. Moreover, the modeling/simulations play an important role for the quantitative understanding. Besides research teams in the project, the science center has been operated. The science data from the project have been archived. Moreover, the science center has developed an integrated data analysis software that are a plug-in for SPEDAS in cooperation with the THEMIS mission. These data and softwares are available via the ERG-Science Webpage (<http://ergsc.stelab.nagoya-u.ac.jp>). In this presentation, we will talk about an overview of the ERG project and discuss the international collaborations with Van Allen Probes, MMS, THEMIS, Cluster, etc and ground network observations under the framework of Heliosphere/Geospace (H/GSO) system observatory.

Keywords: Geospace Exploration, International Collaboration

MMS High time resolution measurements of kinetic plasma turbulence in Earth's magnetosheath and upstream solar wind

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Kinetic plasma turbulence is known to be widespread in both solar wind and magnetosheath plasmas. The relationships between kinetic plasma turbulence and collisionless magnetic reconnection are likely myriad and complex. Plasma and magnetic field measurements are provided by MMS at unprecedented cadences, up to 133 Hz for sparsely sampled 3D electron distribution functions. Such fast measurements enable use of new windows into the kinetics of plasma turbulence in Earth's magnetosheath and the nearby solar wind. We will present examples of the turbulence signatures observed in the plasma and magnetic field observations on board MMS during the first Phase (1A) of the mission.

Magnetic energy dissipation of plasma sheet under coupling of magnetic reconnection and lower hybrid drift instability

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Understanding of the magnetic energy dissipation process in a current sheet is an important problem in space plasma as well as in MMS science. So far the inertia resistivity by reconnection and the current driven instability such as the lower hybrid drift instability (LHDI) have been discussed as possible candidates for the origin of microscopic process of magnetic energy dissipation. It is well known that while the LHDI is mainly excited in the plasma sheet boundary, the inertia resistivity effectively works at the neutral sheet. Therefore, the role of the LHDI to the magnetic field dissipation is less important than the inertia resistivity involved in the magnetic reconnection. However, the activity of lower hybrid drift waves together with the electron heating is commonly observed in the plasma sheet boundary by modern satellite observations, and their impact on the magnetic field dissipation at the neutral sheet is not necessarily neglected. In addition, the nonlinear coupling between them is not theoretically understood yet. In this talk, we study the coupling of the collisionless reconnection and the LHDI by using a three-dimensional PIC simulation by paying a special attention to electron heating and the magnetic energy dissipation, and discuss the importance of the current driven instability during magnetic reconnection.

Keywords: magnetic reconnection, plasma sheet, plasma heating, lower hybrid drift instability

The Electron Diffusion Region in Asymmetric Magnetic Reconnection with Guide Fields

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The launch of the Magnetospheric Multiscale mission is leading to a revolution in our understanding of the way magnetic reconnection works. During the first orbit phases, MMS science focuses on asymmetric reconnection, as is commonly found at the Earth's magnetopause. MMS observations have begun to support the view that reconnection operates primarily as a quasi-laminar process, supporting one class of theoretical predictions and a number of concurrent simulations. In this presentation, we present a detailed look at model predictions pertaining to asymmetric magnetic reconnection with a guide magnetic field, and we present a comparison to recent MMS observations.

Keywords: Magnetospheric Multiscale, Magnetic reconnection, Magnetopause

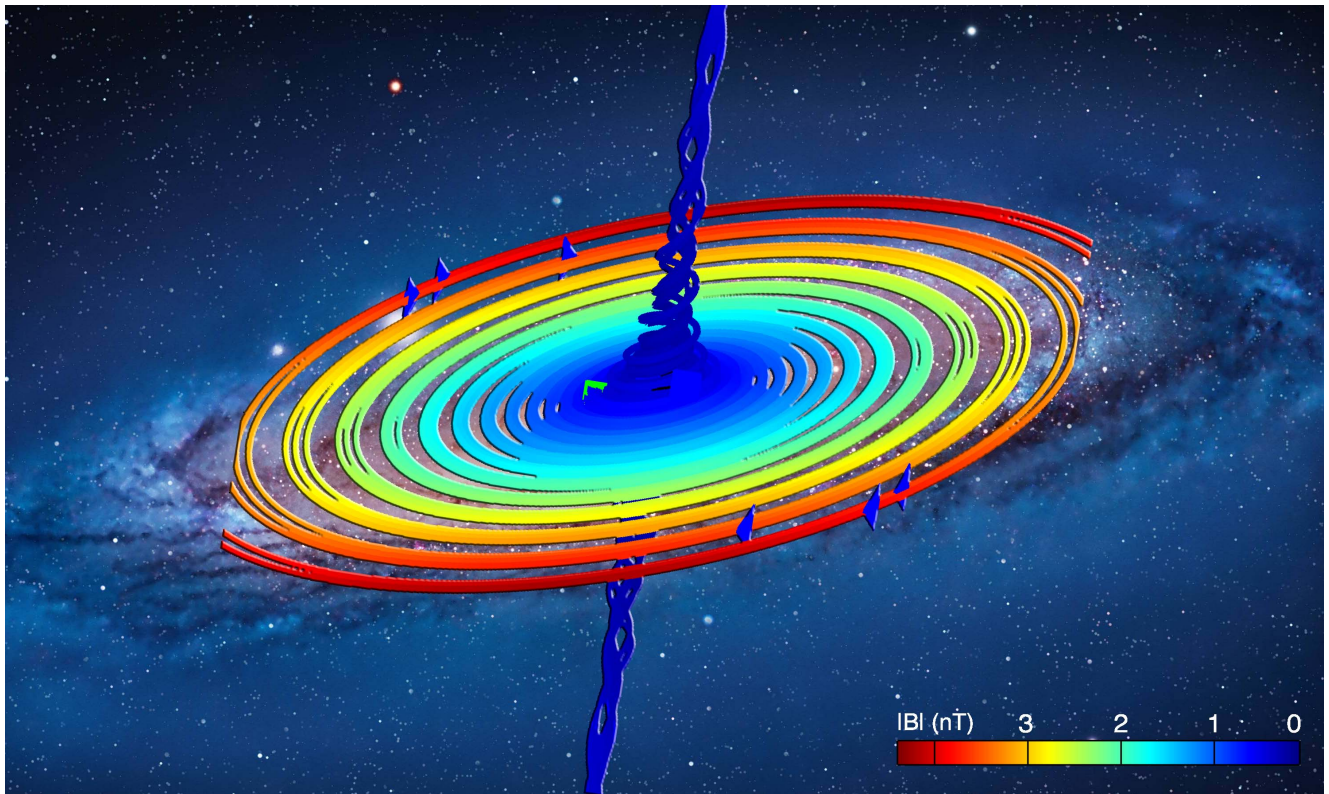
How to find magnetic nulls and reconstruct field topology with MMS data?

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In this study, we apply a new method—the first-order Taylor expansion (FOTE)—to find magnetic nulls and reconstruct magnetic field topology, in order to use it with the data from the forth-coming MMS mission. We compare this method with the previously used Poincare index (PI), and find that they are generally consistent, except that the PI method can only find a null inside the spacecraft (SC) tetrahedron, while the FOTE method can find a null both inside and outside the tetrahedron and also deduce its drift velocity. In addition, the FOTE method can (1) avoid limitations of the PI method such as data resolution, instrument uncertainty (Bz offset), and SC separation; (2) identify 3D null types (A, B, As, and Bs) and determine whether these types can degenerate into 2D (X and O); (3) reconstruct the magnetic field topology. We quantitatively test the accuracy of FOTE in positioning magnetic nulls and reconstructing field topology, by using the data from 3D kinetic simulations. The influences of SC separation ($0.05\sim 1 d_i$) and null-SC distance ($0\sim 1 d_i$) on the accuracy are both considered. We find that: (1) for an isolated null, the method is accurate when the SC separation is smaller than $1 d_i$, and the null-SC distance is smaller than $0.25\sim 0.5 d_i$; (2) for a null pair, the accuracy is same as in the isolated-null situation, except at the separator line, where the field is nonlinear. We define a parameter in terms of the eigenvalues of the null to quantify the quality of our method—the smaller this parameter the better the results. Comparing to the previously used one, this parameter is more relevant for null identification. Using the new method, we reconstruct the magnetic field topology around a radial-type null and a spiral-type null, and find that the topologies are well consistent with those predicted in theory. We therefore suggest using this method to find magnetic nulls and reconstruct field topology with four-point measurements, particularly from Cluster and the forth-coming MMS mission. For the MMS mission, this null-finding algorithm can be used to trigger its burst-mode measurements.

Keywords: Magnetic null, MMS mission, Magnetic reconnection, Topology , Reconstruction



Structure of the magnetopause during quasi-continuous spatially-extended magnetic reconnection: Geotail and MMS conjunction on 2015-10-02

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We present observations on 2 October 2015 when Geotail, near the Earth's equatorial plane, and Magnetospheric Multiscale (MMS), at mid-southern latitudes, simultaneously traversed the Earth's postnoon magnetopause and detected southward magnetic reconnection jets under southward interplanetary magnetic field (IMF) conditions. Such fortuitous observations allow us to estimate the length of the reconnection site, and to reveal spatial evolution of the jets along the magnetopause. Our observations show that the primary reconnection X-line under modest solar wind Alfvén Mach number condition can be extended over a wide range of local time and remain active for hours. During a due southward IMF interval when anti-parallel reconnection was occurring, MMS encountered a localized ion-scale current sheet within the jet far downstream (>300 ion inertial lengths) of the primary reconnection site. The current sheet contained super-Alfvénic perpendicular electron flow, perpendicular electric current of order 500 nA/m^2 , electron flow reversal, and both Hall current and Hall magnetic field signatures. The observations are consistent with the occurrence of secondary reconnection within the jets of quasi-continuous spatially-extended reconnection. It appears that the primary site of magnetopause reconnection under favorable conditions is two-dimensional, but the resulting reconnection jets and secondary reconnection are three-dimensional.

Keywords: magnetic reconnection, magnetopause, ion diffusion region

Shift of the magnetopause reconnection line to the winter hemisphere under southward IMF conditions: Geotail and MMS observations

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Recent global modeling studies and remote observations have indicated that the location of the dayside magnetopause reconnection line under southward interplanetary magnetic field (IMF) conditions tend to shift toward the winter hemisphere from the subsolar point owing to the effect of geomagnetic dipole tilt. We examined this idea using the data obtained by the Geotail and MMS (Magnetospheric Multi Scale mission) spacecraft near the GSM $Z = 0$ plane under southward IMF conditions. Around 0213 UT on 18 November 2015, the MMS spacecraft observed southward reconnection jets at the subsolar magnetopause (GSM $Z = -0.33 R_E$) under southward and dawnward IMF conditions. We estimated the plane of the magnetopause current sheet using the minimum variance analysis of current densities that were derived by the curlometer technique. The N axis of the LMN coordinates was defined as the normal to this plane. The L axis was defined as the nearest direction in this plane from the maximum variance direction of magnetic fields. Using the ratio between the N and L components of the magnetic field, the reconnection rate was estimated to be 0.03. The distance between the ion edge and the center of the current sheet (weakest magnitude of the magnetic field) was estimated as ~540 km, using the N component of the deHoffmann-Teller velocity and the time period between the two. On the basis of the estimated distance and reconnection rate, the reconnection line was ~2.8 R_E northward from the MMS. This corresponds to GSM $Z \sim 2.5 R_E$. About 30 minutes later, the Geotail spacecraft also observed southward reconnection jets at the dawnside magnetopause even though Geotail was in the northern hemisphere (GSM $Z = 1.3 R_E$). The effect of IMF B_y was very small around this time, since the MMS spacecraft observed purely southward directed magnetic fields in the magnetosheath. These observations are consistent with the idea that the dayside magnetopause reconnection line shifts toward the winter hemisphere under southward IMF conditions.

Keywords: MMS spacecraft, magnetic reconnection, magnetopause, Geotail spacecraft

Locations of Magnetopause Magnetic Reconnection: The Role of Magnetosheath Plasma Pressure

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Question of where magnetic reconnection (MR) occurs or equivalently what mechanisms control the initiation of MR on the dayside magnetopause is intensively studied but not fully understood. Here, a novel statistic study reveals that magnetosheath thermal pressure maximizes near the subsolar point, its location, however, is modified by the dipole tilt angle in a manner the same as MR locations are. The maximum sheath thermal pressure, cooccurring with the enhanced magnetic pressure immediately inside the magnetopause, is though to be linked to a maximum magnetopause current density, where tearing mode instabilities tend to develop and MR initiates. The high pressure region shifts from the subsolar region due to magnetopause reshaping when the dipole tilt angle varies. The sheath flow stagnation point, however, remains unchanged at the subsolar point, and Xlines thus are embedded within sub Alfvénic sheath flows and are convected toward high latitudes. The successive Xlines may thus generate flux ropes.

Keywords: Magnetopause, Magnetic Reconnection, Pressure

Structure of the magnetopause observed by MMS and its effects on the Kelvin-Helmholtz instability

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How to cause plasma mixing across different plasma regimes has been one of the fundamental problems in the collisionless plasma physics. At a plasma boundary where different plasma regimes are in contact, there often exists a velocity shear and a density gradient. The Kelvin-Helmholtz instability (KHI) has been studied as a promising mechanism to cause the plasma mixing. Although the importance of the density gradient in the plasma transport across the Earth's magnetopause has previously been pointed out, the detailed structure of the boundary remains unknown due to lack of high-cadence observations across the magnetopause. Based on high time-resolution observations of ions and electrons as well as simultaneous magnetic field by MMS, we investigated the relations between the density gradient and velocity shear at the magnetopause. Based on the observed structure, we implemented a new initial condition for KHI simulations, and effects of the boundary structure on KHI excitation and subsequent plasma mixing is discussed.

Keywords: magnetopause, boundary layer, Kelvin-Helmholtz Instability, plasma mixing, density gradient, MMS

MMS satellites and EISCAT radar observations of dayside flow bursts.

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A magnetic flux transfer event (FTE) was compared with ground radar observations of ionospheric ion flow bursts. Magnetospheric multiscale (MMS) satellites were located near the subsolar magnetopause at approximately 1049 UT on 15 December 2015. MMS satellites observed a southward turning of the interplanetary magnetic field (IMF), followed by a FTE 20 minutes later, and MMS entered the magnetosphere a further 10 minutes later. The European incoherent scatter (EISCAT) VHF radar at Tromso (Norway) was pointed to geographic north, with an elevation angle of 30 degrees, and was monitoring the ionospheric F region between 68 and 72 MLAT at 13 MLT. The Tromso radar did not observe an ionospheric flow burst at the time of the IMF southward turning but instead at the time of the FTE. A 630 nm all-sky imager at Longyearbean (74 MLAT, Norway) observed several poleward moving auroral forms (PMAFs) originating near 74 MLAT but none below 73 MLAT. The most significant PMAF accelerated and became enhanced approximately 3 minutes before the observation of the FTE. FTEs are usually associated with ionospheric flow bursts near the cusp and higher latitudes. In this particular case, it is suggested that the FTE is also associated with an ionospheric flow burst in subauroral latitudes. Such a subauroral flow burst may indicate a rarefaction inflow into the cusp and may occur when significant magnetic flux is removed by a FTE.

Keywords: reconnection, MMS, EISCAT