# MMS AND CLUSTER OBSERVATIONS OF MAGNETIC RECONNECTION

## 1. Overview of the project

***Introduction and Motivation*** Magnetic reconnection is a fundamental physical process that operates within the heliosphere and throughout the universe. It drives plasmas populating the reconnecting magnetic fields to intermix, and converts large amounts of magnetic energy into kinetic energy. The multi-scale nature of reconnection has long been a focus of study in both space and laboratory plasmas: Reconnection has large-scale effects such as influences on the energy budgets, plasma transport, and dynamics of global plasma structures, e.g., in association with the generation of flux transfer events (FTEs) and dipolarization fronts (DFs) and their macroscopic motion. The initiation and reconfiguration of magnetic topology associated with the reconnection are thought to arise as a result of demagnetization of electrons within the small electron diffusion region (EDR). This region is embedded within a much larger ion diffusion region (IDR) where ions are demagnetized. Heavy and/or cold dense ions introduce a new length scale associated with their larger/smaller gyroradius to reconnection. Although IDRs, where Hall physics governs the magnetofluid description, have been identified by their magnetic and electric field geometry, the EDR is difficult to observe primarily because of its small-scale size coupled with the generally long cadences associated with plasma measurements. Important reconnection parameters such as the reconnection rate are, however, controlled by microphysical processes occurring at these EDR/IDR scales. Yet our understanding of the microphysics of reconnection and its meso-macroscale effects on plasma transport/acceleration is far from the completion.

***Objectives and Timeliness*** The Cluster mission [*Escoubet et al*., 2001] has emphasized multi-scale processes occurring throughout the Earth's magnetosphere since 2000. The Magnetospheric Multiscale (MMS) mission [*Burch et al*., 2016], launched in March 2015, helps unravel the mysteries of magnetic reconnection with unprecedented time-resolution measurements of particles and fields. Cluster and MMS constitute, for the first time, two tetrahedral configurations that can investigate multi-scale phenomena simultaneously, enabling more precise mapping of kinetic boundaries in a reconnection region and quantitative testing of micro and meso-scale physics. With large spatial separations between the two missions and different orbital inclinations, MMS and Cluster provide us with an opportunity to capture micro-to-macroscopic pictures of plasma processes, which include the structure and extent of reconnection X-lines, reconnection jets and outflow, the generation, structure, and evolution of FTEs and DFs. Additionally, in conjunction with the Van Allen Radiation Probes, ARTEMIS, and THEMIS, MMS and Cluster provide measurements of spatial and temporal phenomena and global effects of dayside and magnetotail reconnection. Our project will make full use of these unprecedented opportunities to compare, resolve, and understand reconnection process, including FTEs and DFs, etc., as a function of solar activity.

***Merits and Impacts*** So far, space plasma physicists studying reconnection (including FTEs and DFs) who have used Cluster data and now apply their expertise to MMS observations have largely been working separately from each other. In addition, observational researchers who can benefit from collaborations with kinetic code modelers (such as Particle-In-Cell simulators) to interpret in-situ data are often disconnected from modelers. Consequently, it can be difficult to assemble the various findings in this field into a full picture. Our aim is to bring existing and new pieces together to construct the comprehensive picture. We will do so by: compiling a state-of-the-art review article; initiating teamwork between researchers familiar with data analysis and simulations, reconciling findings from both approaches; and launching inter-disciplinary collaborations to significantly advance our understanding of the physics of reconnection. In order to achieve our objectives, we bring together a strong team, composed of top tier researchers from 8 different countries. Our team's combined expertise covers all areas relevant to the proposed research. Our team is, hence, in a unique position to overcome present shortcomings of individual approaches to one of the most fundamental physical phenomena, magnetic reconnection, and to address the science posed above using unprecedented opportunities provided by MMS and Cluster, combined with full particle simulation codes.

## 2. Scientific rationale, goals, and timeliness of the project

The research vision in magnetospheric physics and solar-terrestrial sciences depends critically on a deep understanding of the coupling and interplay of space plasmas at micro-, meso-, and macro-scales. Magnetic reconnection, the subject of our proposed team effort, exhibits a multi-scale nature. Despite decades of observations and theoretical investigations, many fundamental questions concerning the causes and consequences of reconnection remain unanswered. In the following paragraphs, we outline known features from previous studies and the key unresolved problems in reconnection research divided into following sub-topics: the structure and dynamics of reconnection; FTEs; and DFs.

***Dynamics of multi-scale reconnection*** Reconnection has major large-scale implications for the surrounding media, yet the key processes that drive magnetic reconnection occur at very small scales in the diffusion region, where magnetic fields diffuse and reconnect with a new topology. At the thin current sheets (with sharp gradients in the magnetic field) that occur at the Earth's dayside magnetopause and in its nightside magnetotail, particles with vastly different masses cause a structured region wherein the ions (with larger gyro-radius) decouple from the magnetic field at location farther from the X-line (where the magnetic topology changes) than electrons (Figure 1). This separation leads to the formation of a small EDR (where electrons decouple from the magnetic field) embedded within an IDR with characteristic Hall magnetic/electric fields [e.g., *Mozer et al*., 2002]. The magnetic energy stored in the regions adjacent to the current sheet (inflow regions; Figure 1) is released to the plasma, which jets away from the reconnection site on both-side exhaust regions. The diffusion region, in particular, its aspect (length-to-width) ratio, is found to control the rate of release of magnetic energy. Thus the diffusion region of *unknown structure and dynamics* controls the energy conversion in a macroscopic system.

Magnetic field diffusion through the plasma, i.e., the breakdown of the particle-field frozen-in principle (with the left-hand side of the equation below equivalent to 0), is described by the generalized Ohm's law [*Khotyaintsev et al*. 2006]:

$$\mathbf{E} + \mathbf{u} \times \mathbf{B} = \eta \mathbf{J} + \frac{1}{ne}\mathbf{J} \times \mathbf{B} - \frac{1}{ne}\nabla \cdot \mathbf{P}_e + \frac{m_e}{ne^2}\frac{\partial \mathbf{J}}{\partial t}$$

The $\eta\mathbf{J}$ term attributed to classical collisional resistivity can be replaced by turbulent resistivity due to fluctuations in collisionless plasma relevant to our subject. The Hall term, $(1/ne)\ \mathbf{J}\times\mathbf{B}$, associated with differential flow of ions and electrons becomes important at the ion inertial scale ($c/\omega_{pi}$). The third term, the electron pressure tensor term of the order of $\beta_e c/\omega_{pi}$ ($\beta_e$: the ratio of electron pressure to magnetic pressure) is appreciable at both ion and electron scales. The last term, the electron inertia term becomes significant at the electron inertial scale ($c/\omega_{pe}$). Therefore, we rephrase the unknowns of the reconnection diffusion region: **What dynamics on which scales are important to field-line break-up and energy conversion? Which term in Ohm's law contributes to the reconnection electric field? Where/how do the non-isotropy and/or non-gyrotropy of particle distribution functions form and what roles do they play in the physical process underlying reconnection?**

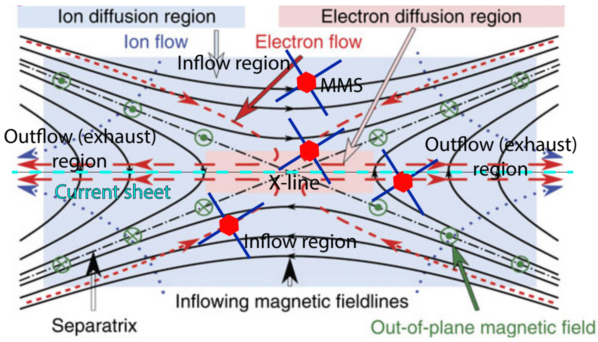


*Figure 1. Adopted from Yamada et al. [2014]. Illustration of the reconnection geometry: inflow regions above and below a current sheet; outflow (exhaust) regions; ion diffusion region (blue shade); electron diffusion region (red shade). Four MMS satellites sketched near the X-line possibly pass the diffusion region, unraveling mysteries of microphysics of magnetic reconnection.*

Numerous studies using full particle-in-cell (PIC) simulations [e.g., *Pritchett*, 2002; *Hesse et al*., 2004; *Scudder and Daughton*, 2008; *Pritchett and Mozer*, 2009] have been performed to investigate the relative roles of each term of the Ohm's law equation in balancing the reconnection electric field. The consensus is that the electric field in the IDR and/or the separatrix region is mainly balanced by the Hall term and that nongyrotropic pressure forces dominate over electron inertial forces in the EDR. More recent theoretical and modeling efforts have shed light on the ion and electron behavior in different boundary layers and parameter regimes of both anti-parallel and guide-field reconnection [e.g., *Egedal et al*., 2013; *Hesse et al*., 2014; *Bessho et al*., 2014; *Shuster et al*., 2015]. For example, the electron distribution exhibits triangular striated structures near the X-line due to particle reflections, while in the EDR downstream of the X-line it features outflow jets with swirls, arcs, and rings [*Shuster et al*., 2015]; Meandering particle motions, due to oppositely-directed magnetic fields, form a crescent-shape distribution, which has recently been reported by MMS observations [*Burch et al*., 2016].

These studies considered plasmas consisting of single ion species, or populations with single ion and electron temperature, although recent observations indicate that heavy ions ($He^+$, $He^{2+}$, $O^+$) and/or cold dense ions are often present near/at the reconnection site. How these heavy and/or cold dense ions of ionospheric origin affect the reconnection process remains poorly understood. Using Cluster observations, *Toledo-Redondo et al*. [2015] showed that cold ions introduce a new length-scale associated with their smaller gyroradius to reconnection. This indicates that different ion populations modify the Hall physics, complicating the structure of the IDR, and differentiate particle heating/acceleration occurring in the IDR and/or separatrices. It is still unclear/controversial how the kinetic nature of different ion species manifests themselves from the large-scale perspective, i.e., how the presence of multi-species ions changes magnetic topology and the reconnection rate. **Cluster and MMS, both instrumented to measure ion mass composition, enable precise mapping of kinetic boundaries in the site of reconnection involving different ion species and quantitative testing of micro and meso-scale physics.**

***The location, extent, and orientation of the reconnection X-line*** Another important unknown in reconnection research is the location, extent, and orientation of the reconnection X-line in a 3-D system (or the magnetic separator in 3-D reconnection [*Lau and Finn*, 1990]). When the magnetic fields at two sides of a planar current sheet shear with an arbitrary angle, Φ, the X-line could develop at any angle from 0 to Φ, given that the fields in the plane normal to the X-line reverse signs across the current sheet. It remains unanswered if there is a principle that determines the orientation of the X-line, which is directly relevant to determine the location of magnetic reconnection on the magnetopause and/or in the magnetotail current sheet. Recent endeavors to address this problem predicted that reconnection occurs in the plane in which the reconnection jet or the reconnection electric field attains its maximum value or the X-line appears to bisect the total magnetic shear angle [*Swisdak and Drake*, 2007; *Schreier et al*., 2010; *Hesse et al*., 2013; *Liu et al*., 2015].

Observationally, the location, extent, and orientation of the X-line are inferred from reconnection outflow jets, patterns of ion dispersions, and in support of ground-based (from radars, all sky imagers, and magnetometers) signatures [e.g., *Phan et al*. 2001; 2006; *Dunlop et al*. 2011]. **Joint MMS and Cluster observations provide a unique opportunity to explore the structure and extent of reconnection X-lines.**

***Flux Transfer Events (FTEs)*** Spacecraft crossing the Earth's magnetopause often observe a single transient structure or a series of a bipolar signature in the magnetic field component normal to the nominal magnetopause ($B_n$). Since *Russell and Elphic* [1978] first termed this signature a flux transfer event (FTE), numerous *in-situ* observations [e.g., *Paschmann et al*., 1982; *Sibeck and Siscoe*, 1984] have identified other FTE signatures, including either an enhancement or decrease in the magnetic field strength at (or bounding, in the case of crater FTEs) the center of the $B_n$ reversal and an enhancement in the total pressure at the center of FTEs, where the pressure force balances the magnetic tension force [*Ieda et al*., 1998]. FTEs detected inside the magnetosphere or the magnetosheath contain plasmas from both regions [*Klumpar et al*., 1990].

Various mechanisms for FTE generation invoke 1) transient bursts of dayside reconnection [e.g., *Russell and Elphic*, 1978; *Southwood et al*., 1988], 2) temporal modulation of the reconnection rate during continuous reconnection [*Phan et al*., 2004], or 3) multiple X-lines (in 2-D representations) or separator lines (in 3-D representations) [e.g., *Raeder*, 2006; *Hasegawa et al*., 2010]. These different generation mechanisms necessarily give rise to different magnetic topology or magnetic field connectivity within and around the FTEs. *Fear et al*. [2008] categorized various flux rope models into three types: the elbow-shaped flux-bundle FTEs, single X-line FTEs, and multiple X-line FTEs, corresponding to case 1) to 3), respectively.

Multi-spacecraft missions have advanced our understanding of the FTE structure, motion, and extent. *Fear et al*. [2008] used Cluster observations to describe an FTE with a much larger azimuthal (dawn-dusk) than north/south extent, which is inconsistent with the elbow-shaped flux tube model. *Hasegawa et al*. [2010] reported THEMIS observation of an FTE between the two converging jets, and therefore suggested the event formed via multiple X-line reconnection [e.g., *Raeder*, 2006]. *Øieroset et al*. [2011] presented similar observations of bidirectional jets converging toward an FTE. Observations of electrons that were not trapped within the core of the event demonstrated that the event was three-dimensional and had an open magnetic field topology rather than the structure of a two-dimensional magnetic island. *Owen et al*. [2001] and *Varsani et al*. [2014] used Cluster observations to define the magnetic field connectivity inferred from the magnetic field and electron signatures. *Farrugia et al*. [2011] presented crater FTEs with multiple layers that can be identified by their magnetic, electric, and plasma signatures.

Previously reported magnetopause FTEs often have scale sizes comparable to one Earth radius ($R_E$). *Drake et al*. [2006] used PIC simulations to show the formation of secondary islands with much smaller, only a few to several ion inertial length ($d_i$), scale sizes in the exhaust region during magnetic reconnection. They pointed out that stronger guide fields result in longer electron current layers downstream from X-lines. Longer electron current sheets are more likely to be unstable to secondary island formation. *Hwang et al*. [2016] reported MMS observations of ion-scale FTEs formed along a magnetopause current layer between the two X-lines that was unstable to the tearing instability, generating multiple ion-scale flux-rope-type secondary islands. Likewise, **the four MMS spacecraft, separated by less than 100 km, enable us to explore the substructure and topology of FTEs on micro-scales. In conjunction with Cluster measurements, we seek to investigate the shape, extent, and motion of FTEs as well as how they generate, coalescence, and propagate affecting the magnetopause current system and plasma mixing and transport.**

***Dipolarization Fronts (DFs)*** DFs are a phenomenon commonly detected near the equatorial plane of Earth's nightside plasma sheet. They are characterized by sharp increases in the magnetic field component normal to the equatorial plane of the magnetosphere, increases of magnetic pressure, and decreases of plasma pressure across the front. Numerous DF observations in the near-Earth plasma sheet seen by the Cluster spacecraft [e.g., *Hwang et al*., 2011; *Fu et al*., 2011; 2012; 2013] and THEMIS [e.g., *Runov et al*., 2009; *Sergeev et al*., 2009; *Ashour-Abdalla et al*., 2011] have shown that DFs predominantly propagate earthward along the radial direction and are often embedded within fast earthward flows, i.e., bursty bulk flows [*Angelopoulos et al*., 1999].

The plasma and magnetic-field variations across DFs indicate that 1) they can result from magnetic reconnection in which the exhaust jets and entrained magnetic fluxes from the reconnection site pile up forming a front of increased magnetic flux [e.g., *Fu et al*., 2013], 2) they carry an entropy-depleted flux tube, or a localized *plasma bubble* behind them [*Birn et al*., 2004; *Hwang et al*., 2011], and 3) they provide a source region of both cross-tail (duskward) and field-aligned currents [e.g., *Liu et al*., 2013; *Sun et al*., 2013]. DFs have drawn wide attention because they significantly affect the acceleration and transport of plasmas. The energization is attributed to betatron and/or (first order) Fermi acceleration associated with the local magnetic pile-up signature of DFs and the large-scale reconfiguration (shortening) of the magnetic fields caused by radial convection of DFs [e.g., *Fu et al*., 2011] and to other nonadiabatic processes, including wave-particle interactions [*Deng et al*., 2010; *Hwang et al*., 2014].

*Hwang et al*. [2015] reported, using MMS statistics of DFs, diverse (radially inward, azimuthally duskward, northward) propagation of DFs and different patterns of particle energization depending on the propagation of DFs and their detection location. **The high-resolution data from MMS will facilitate our exploration of detailed magnetic topology and particle energization at/around DFs. Important unknowns to be clarified by our ISSI team include: the substructure of the DF (e.g., bifurcated ion and electron current sheet layers within the DF, inferred by *Klimas and Hwang* [2016]); the magnetic topology of the DF including the negative $B_z$ dip region ahead of DFs; and particle energization in terms of DF sub-layers and topology.**

***Goals*** Based on knowns an unknowns stated above, we aim to advance current understanding of reconnection by answering the following outstanding questions:

**Q1. Reconnection**
- ✓ **Where does reconnection occur? What determines the structure and extent of reconnection X-lines?**
- ✓ **What dynamics at what scales (e.g., which term in the generalized Ohm's law) is important in topology change and energy conversion?**
- ✓ **How do particle distribution functions form/vary in space and time?**
- ✓ **How does the presence of multi ion populations change magnetic topology and the reconnection rate?**

**Q2. Flux transfer events**
- ✓ **How are FTEs generated? How do their shape and extent evolve and propagate?**
- ✓ **What are the substructure and magnetic topology/connectivity within FTEs?**
- ✓ **How do FTEs affect the magnetopause current and plasma mixing and transport?**

**Q3. Dipolarization fronts**
- ✓ **What are the substructure (e.g., current sheet layers) and magnetic topology of the DF including the negative $B_z$ dip region ahead of DFs?**
- ✓ **Where and how effectively are particles energized in terms of DF sub-layers and topology?**

***Timeliness*** The ESA's Cluster mission has provided the first four-point measurements designed to distinguish between temporal and spatial signatures of plasma structures in geospace. This simultaneous four-point capability that is essential to unravel the critical micro- to meso-scale phenomena has innovatively advanced space in-situ observations. The MMS mission is a successor in evolution of multi-spacecraft measurements. The specific goal of MMS is to probe the electron-scale physics of reconnection by flying four spacecraft at inter-spacecraft ranges down to 10 km. In particular, the four MMS satellites provide 3-D particle distributions (by FPI) at an unprecedented time resolution: 30 ms for electrons and 150 ms for ions. The extremely high-resolution particle distributions enable us to map or reconstruct the reconnection topology and behavior of each plasma population participating in reconnection in each substructure of the reconnection current sheet layer.

Cluster and MMS will provide a micro-to-macro combination of observations, with large spatial separations between the two missions providing a macroscopic picture of plasma processes and structure, and two tetrahedrons that can investigate multi-scale (<10 km) phenomena simultaneously. An example of orbit phasing is shown in Figure 2. In late 2016 the MMS spacecraft will increase apogee to move deeper into the magnetotail. The joint MMS-Cluster configuration highlights the unique double-opportunity orbits in which Cluster cross the magnetopause outbound at high latitude at a similar local time to MMS. During the inbound crossing, Cluster is at a lower latitude, similar to MMS, but separated in local time. These orbit configurations provide a variety of situations to examine the extent of reconnection X-lines/FTEs/DFs and their local structure and effects, enabling us to answer our questions.

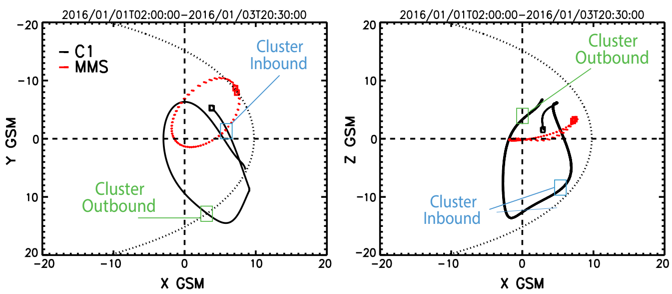


*Figure 2. Example orbits showing the conjunction opportunities between Cluster (black trace) and MMS (red).*

## 3. Expected output and impacts

Following steps will lead us to answer our science questions:
***Step 1*:** we will work on a review of the current knowledge, by compiling and discussing observational and numerical findings from individual researchers/groups consisting of our team.
***Step 2*:** we will set up collaborations between groups approaching the problems using observational and numerical methodology to facilitate profound interpretation of in-situ data, reconcile differences, and put them together to construct a complete picture/understanding of reconnection/FTEs/DFs.
***Step 3*:** we will arouse space science communities' attention to outcomes from our ISSI activities to build bridges between world-wide communities studying relevant (directly or indirectly) subjects.

Via *Step 1* and *2*, we expect the understanding of the reconnection physics to be significantly advanced. We expect to compile our understanding and views of reconnection/FTEs/DFs into a state-of-the-art review paper. All the team members including young scientists will coauthor the paper to be submitted to a high-impact peer-reviewed journal.

Via *Step 2*, we expect multiple papers about the structure and dynamics of reconnection/FTEs/DFs and particle distributions near/at the reconnection sites, resulting from collaborations between groups working on observations and simulations and/or among individual team members.

Via *Step 3*, our project will directly contribute to the magnetospheric research community, studying reconnection/ FTEs/DFs. Interdisciplinary communications between groups working on directly or indirectly relevant topics will widen our vision for the fundamental physics underlying reconnection and interplaying between multi-scale phenomena.

Via *Step 1-3*, our project will contribute to the Cluster and MMS missions by help maximizing its scientific gain, developing analysis tools using the MMS/Cluster data (e.g., for finding a magnetic null, *Fu et al*. [2015]), and possibly influencing on MMS/Cluster data acquisition planning.

## 4. Added value from ISSI

Space plasma physicists studying reconnection/FTEs/DFs who have used Cluster data and now apply their expertise to MMS observations have largely been working separately from each other. In addition, observational researchers who can benefit from collaborations with PIC simulators to perform profound interpretation of in-situ data are often disconnected from modelers. Consequently, pieces of the findings in this field cannot readily be assembled into a full picture. ISSI will provide us a unique opportunity to overcome this situation, enabling us to construct a comprehensive picture, to build international collaborations among team members, and to perform inter-disciplinary research.

## 5. Confirmed team members

To achieve our objectives, we bring together a strong multi-discipline team, composed of 9 data-analyzing researchers and 2 PIC simulators with young scientists from 8 different countries. Our team's combined expertise covers all areas relevant to the proposed research.

| | | |
|---|---|---|
| **Nicolas Aunai** | Laboratory of Plasma Physics, Ecole Polytechnique | France |
| **Jonathan P. Eastwood** | Imperial College, London | UK |
| **Philippe Escoubet** | European Space Agency | Nederland |
| **Robert C. Fear** | University of Southampton | UK |
| **Huishan Fu** | Beihang University | China |
| **Kyoung-Joo Hwang (Team leader)** | NASA Goddard Space Flight Center/UMBC | USA |
| **Yuri Khotyaintsev** | Swedish Institute of Space Physics | Sweden |
| **Giovanni Lapenta** | Centrum voor mathematische Plasma Astrofysica | Begium |
| **Benoit Lavraud** | Institute de Recherche en Astrophysique et Planétologie | France |
| **David G. Sibeck** | NASA Goddard Space Flight Center | USA |
| **Sergio Toledo-Redondo** | European Space Agency, ESAC | Spain |

## 6. Schedule of the project

We propose to meet three times (Fall 2016, Spring/Fall 2017) at the ISSI facilities in Bern, Swiss. We will hold regular teleconferences to monitor and discuss the work progress. Work plans for the meetings are shown below:

***2016 Fall meeting (1 week)*:**

- Review/discuss previous and recent findings from simulations and observations
- Initiate inter-disciplinary collaborations between team members with respect to specific topics: e.g., the structure and dynamics of reconnection, FTEs, and DFs
- Outline the structure of the review paper with determination of the leading authors and contributing collaborators

***2017 Spring meeting (3 days)*:**

- Discuss progress on inter-disciplinary efforts to draft corresponding research papers
- Update/assess the status of review paper and its content in light of new results from discussion

***2018 Spring meeting (3-4 days)*:**

- Synthesize inter-disciplinary works on specific topics; finalize/submit research papers and a review paper
- Discuss inputs to broad science communities and MMS/Cluster data acquisition planning and future collaboration

## 7. Facilities required

Our meeting room that can accommodate about 15 people should be equipped with projection facilities and a white board. We may also need teleconference equipment in case that some team members cannot attend to one of the three meetings. As all team members and young scientists will bring their own laptops, we will need access to a wireless internet connection and a nearby printer.

## 8. Financial support requested

We require the standard financial support package for international teams. This shall include the travel costs of the team leader (approx. 1200 €), and hotel expense and per diem for all team members for the three meetings. The hotel and per diem costs for a group of 3 young scientists per each meeting (to be identified once the proposal is selected) shall not exceed 20% of the financial means allotted to the team members.

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# Nicolas Aunai

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My research is focused on plasma physics phenomena occuring in space and astrophysical environements. I write and use plasma simulation codes and analyze spacecraft data. My primary research topic is the study of magnetic reconnection.

## Positions

| | | |
|---|---|---|
| *2014-* | Laboratoire de Physique des Plasmas | Researcher at CNRS |
| *2013-2014* | Institut de Recherche en Astrophysique et Planétologie | **PI ANR project "retour postdoc"**<br>~ 335k€, (IRAP, LPP and NASA) including funding of 1 PhD |
| *2011-2013* | NASA Goddard Space Flight Center, Greenbelt MD, USA | **NASA Postdoctoral Program Fellow**<br>*Advisor:* Dr Michael Hesse |
| *2007-2010* | Laboratoire de Physique des Plasmas, Palaiseau, France | **PhD Student**<br>*PhD Advisor:* Dr Gerard Belmont<br>*PhD Co-Advisor:* Dr Roch Smets<br>*Sujet : Numerical simulation of magnetic reconnection: kinetic mechanisms underlying the ion fluid dynamics* |

## EDUCATION

| | | |
|---|---|---|
| *2007-2010* | Université Paris-Sud Orsay, France | **PhD Thesis**<br>February 11th 2011 at Ecole Polytechnique |
| *2004-2007* | University Paris-Sud | **Magistère in Fundamental Physics and Astrophysics** |

## TEACHING

| | | |
|---|---|---|
| *2007-2010* | University of Versailles | **Électromagnetism and wave optics** |
| *2008-2010* | University of Versailles | **Special relativity and nuclear physics** |

## Projects and awards

- René Pellat award 2012 from French Physics Society.
- NASA Postdoctoral Program (2011-2013).
- CNES Postdoc Project - 2013.
- AXA Reseach Funds Project - 2013.
- **ANR project 335k€(en cours)**

## RELEVANT PUBLICATIONS

- S. Toledo-Redondo, M. Andre, A. Vaivads, Y. Khotyaintsev, B. Lavraud, D. Graham, A. Divin, **N. Aunai** *Cold ion heating at the dayside magnetopause during magnetic reconnection* Geophysical Research Letters, Volume 43, Issue 1, pp. 58-66 http://dx.doi.org/10.1002/2015GL067187
- **N. Aunai**, M. Hesse, M. Kuznetsova, *Electron nongyrotropy in the context of collisionless magnetic reconnection.* Phys. Plasmas 20, 092903 (2013) 10.1063/1.4820953
- **N. Aunai**, M. Hesse, S. Zenitani, M. Kuznetsova, C. Black, R. Evans and R. Smets, *Comparison between hybrid and fully kinetic simulations of asymmetric magnetic reconnection: coplanar and guide field configurations.* Phys. Plasmas 20, 022902 (2013) doi 10.1063/1.4792250
- **N. Aunai**, G. Belmont, and R. Smets, *Proton acceleration in antiparallel collisionless magnetic reconnection: Kinetic mechanisms behind the fluid dynamics*, J. Geophys. Res., 116(A), 09232, doi:10.1029/2011JA016688.
- **N. Aunai**, G. Belmont, R. Smets, *The proton pressure tensor as a new proxy of the proton decoupling region in collisionless magnetic reconnection.* Ann. Geophys., 29, 1571-1579, doi:10.5194/angeo-29-1571-2011, 2011

**Jonathan P. Eastwood**

**Professional Preparation**

| | |
|---|---|
| 2000 | MSci. (1st with Honors), Physics with Year in Europe, Imperial College London, UK |
| 2003 | Ph.D., Physics, Imperial College London, UK |

**Appointments**

| | |
|---|---|
| 10/2003 – 12/2003 | Research Assistant, Dept. of Physics, Imperial College London, UK |
| 01/2004 – 12/2005 | NRC Resident Research Associate, NASA Goddard Space Flight Center, USA |
| 01/2006 – 01/2010 | Assistant Research Physicist, Space Sciences Laboratory, UC Berkeley, USA |
| 01/2010 – 12/2014 | STFC Advanced Fellow, Dept. of Physics, Imperial College London, UK |
| 10/2012 – present | Lecturer, Dept. of Physics, Imperial College London, UK |

**Recent Relevant Publications**

Ion dynamics near magnetotail dipolarization fronts associated with magnetic reconnection, J. P. Eastwood, M. V. Goldman, H. Hietala, D. L. Newman, R. Mistry, and G. Lapenta, J. Geophys. Res., 120, 511-525, doi:10.1002/2014JA020516, 2015.

Energy partition in magnetic reconnection in the Earth's magnetotail, J. P. Eastwood, T. D. Phan, J. F. Drake, M. A. Shay, A. L. Borg, B. Lavraud and M. G. G. T. Taylor, Phys. Rev. Lett., 110, 225001, 2013.

Survival of flux transfer event (FTE) flux ropes far along the tail magnetopause, J. P. Eastwood, T. D. Phan, R. C. Fear, D. G. Sibeck, V. Angelopoulos, M. Øieroset and M. A. Shay, J. Geophys. Res., 117, A08222, doi:10.1029/2012JA017722, 2012.

Average properties of the magnetic reconnection ion diffusion region in the Earth's magnetotail: The 2001-2005 Cluster observations and comparison with simulations, J. P. Eastwood, T. D. Phan, M. Øieroset and M. A. Shay, J. Geophys. Res., 115, A08215, 2010.

Asymmetry of the Diffusion Region Hall Electric and Magnetic Fields During Guide Field Reconnection: Observations and Comparison with Simulations, J. P. Eastwood, M. A. Shay, T. D. Phan and M. Øieroset, Phys. Rev. Lett., 104, 205001, 2010

**Relevant Mission Involvement**

*In flight:* ***Magnetospheric Multi-Scale*** (NASA): Interdisciplinary Science Team Member / ***Cluster*** (ESA): Co-Investigator (FGM) / ***THEMIS-ARTEMIS*** (NASA): Science Team Member
*In Development:* ***THOR*** (ESA, M4 mission candidate): Co-Principal Investigator (Magnetometer) / ***Solar Orbiter*** (ESA, Launch 2017): Co-Investigator (MAG and RPW) / ***JUICE*** (ESA, Launch 2022): Co-Investigator (JMAG)

**Participation in earlier ISSI activities**

2016: ISSI workshop 'Scientific foundations of space weather'
2014-: ISSI intl. team 307 'Small Scale Structure and Transport During Magnetopause Magnetic Reconnection: from Cluster to MMS (ISSI - ISSI Beijing Team)' (Leader: M. Dunlop)
2013-2015: ISSI intl. team 290 'Ion and Electron Bulk Heating by Magnetic Reconnection' (Leader: T. Phan)
2013: Convener, ISSI workshop: 'Multi-scale structure formation and dynamics in cosmic plasmas' (SSSI v. 51)
2012-2014: ISSI intl. team 214 'Flow-driven instabilities of the Earth-Sun system' (Leader: C. Foullon)
2009-2011: ISSI intl. team 145 'Conjugate response of the dayside magnetopause and dawn/dusk flanks using Cluster-THEMIS conjunctions and ground based observations' (Leader M. Dunlop)
April 2010: participated in ISSI super-convenors meeting on the topics of possible future ISSI workshops on 'Space plasma science and beyond'
2007: Co-Author, ISSI Scientific Report SR-008 'Multi-spacecraft analysis methods revisited'
2004-2005: ISSI intl. team 61 'Production and Transport of 1-30 keV Upstream Ions' (Leader C. Mazelle)
2003-2004: ISSI workshop 'Outer Magnetospheric Boundaries: Cluster Results' (SSSI v. 20)

# C. Philippe Escoubet

Philippe Escoubet is project scientist for the Cluster mission and study scientist for the THOR and SMILE missions at the European Space Agency. His main scientific interest is Sun-Earth connection and in particular solar wind plasma entry in the magnetosphere. He is specialized in data analysis of plasma, electric and magnetic field instruments. He is Co-Investigator on various space missions: Cluster (CIS and ASPOC instruments), SMART-1 (SPEDE), Double Star (ASPOC and HIA), THEMIS, Bepi-Colombo (PICAM) and MMS (ASPOC). He is author or co-author of 130 refereed publications. He has been editor of special issues and books in Space Science Review, Astrophysics and Space Science proceedings, Annales Geophysicae and associated editor of Journal of Geophysics Research (2008-2009). He has organized 24 Cluster workshops and special sessions at AGU, EGU, COSPAR and IAGA. He was vice-Chair and now Chair of COSPAR Commission D3 (Magnetosphere). He is member of the International Living With a Star steering committee since 2009 and Chair since 2013.

*Selected publications*:

Berchem, J., R. L. Richard, C. P. Escoubet, S. Wing, and F. Pitout, Asymmetrical response of dayside ion precipitation to a large rotation of the IMF, J. Geophys. Res. Space Physics, 121, 263–273, doi:10.1002/2015JA021969, 2016.

Escoubet, C. P., Masson, A., Laakso, H., and Goldstein, M. L.: Recent highlights from Cluster, the first 3-D magnetospheric mission, Ann. Geophys., 33, 1221-1235, doi:10.5194/angeo-33-1221-2015, 2015.

Escoubet, C. P., Berchem, J., Trattner, K. J., Pitout, F., Richard, R., Taylor, M. G. G. T., Soucek, J., Grison, B., Laakso, H., Masson, A., Dunlop, M., Dandouras, I., Reme, H., Fazakerley, A., and Daly, P.: Double cusp encounter by Cluster: double cusp or motion of the cusp?, Ann. Geophys., 31, 713-723, doi:10.5194/angeo-31-713-2013, 2013.

Pitout, F., Escoubet, C. P., Taylor, M. G. G. T., Berchem, J., and Walsh, A. P.: Overlapping ion structures in the mid-altitude cusp under northward IMF: signature of dual lobe reconnection? *Ann. Geophys.,* 30, 489-501, doi:10.5194/angeo-30-489-2012, 2012.

Escoubet, C.P., J. Berchem, J.M. Bosqued, K. Trattner, et al., Effect of a northward turning of the IMF on cusp precipitation as observed by Cluster, *J. Geophys. Res*., 113, doi:10.1029/2007JA012771, 2008.

Escoubet C. P., J. M. Bosqued, J. Berchem, K. Trattner, et al., Temporal evolution of a staircase ion signature observed by Cluster in the mid-altitude polar cusp, *Geophys. Res. Lett.,* 33, No. 7, 2006.

Liu Z. X., C. P. Escoubet, Z. Pu, H. Laakso, J. K. Shi, C. Shen, and M. Hapgood, The Double Star mission, *Annales Geophysicae*, 23, 2707–2712, 2005.

Escoubet, C. P., M. Fehringer, M. Goldstein, The Cluster Mission, *Ann. Geophys*., 10, 19, 2001.

Escoubet, C. P., M. F. Smith, S. F. Fung, P. C. Anderson, R. A. Hoffman, E. M. Basinska, and J. M. Bosqued, Staircase ion signature in the polar cusp: A case study, Geophys. Res. Lett., 19, 1735, 1992.

# Dr. Robert Fear

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**Education:**

2006 Ph.D. (Cluster multi-spacecraft observations of flux transfer events), UCL

2002 M.Sci. (Physics with Space Science), University College London (UCL).

**Positions held:**

2014— Head of Space Environment Physics Group, University of Southampton

2014— STFC Ernest Rutherford Fellow, Space Environment Physics Group, Univ of Southampton

2013-14 STFC Ernest Rutherford Fellow, Radio & Space Plasma Physics Group, Univ of Leicester

2011— Ground-based instrumentation rep, Cluster Spacecraft Operations Working Group

2007— Member (Chair 2009-14), SuperDARN Spacecraft Working Group

2006-13 Research Associate, Radio & Space Plasma Physics Group, University of Leicester

**Awards**

2010, 2013 University of Leicester merit award

2005, 2015 ESA award for outstanding contribution to the Cluster mission

**Research interests:**

Large-scale solar wind-magnetosphere-ionosphere coupling. Global magnetospheric dynamics using combined in situ and ionospheric data. Northward IMF dynamics. Formation and evolution of transpolar arcs and other polar cap auroras. Timescales of large-scale magnetospheric convection. Formation, structure and global contribution of flux transfer events (FTEs).

**Selected recent publications:**

Fear, R. C., S. E. Milan, J. A. Carter and R. Maggiolo, The interaction between transpolar arcs and cusp spots, Geophys. Res. Lett., 42, 9685-9693, doi:10.1002/2015GL066194, 2015

Trenchi, L., M. F. Marcucci, and R. C. Fear, The effect of diamagnetic drift on motion of the dayside magnetopause reconnection line, Geophys. Res. Lett., 42, 6129-6136, 2015

Carter, J. A., S. E. Milan, R. C. Fear, A. Kullen and M. R. Hairston, Dayside reconnection under IMF $B_Y$ dominated conditions: the formation and movement of bending arcs, J. Geophys. Res., 120, 2967-2978, doi:10.1002/2014JA020809, 2015

Fear, R. C., S. E. Milan, R. Maggiolo, A. N. Fazakerley, I. Dandouras and S. B. Mende, Direct observation of closed magnetic flux trapped in the high-latitude magnetosphere, Science, 346, 1506–1510, doi:10.1126/science.1257377, 2014

Fear, R. C., S. E. Milan and K. Oksavik, Determining the axial direction of high-shear flux transfer events: Implications for models of FTE structure, J. Geophys. Res., 117, A09220, doi:10.1029/2012JA017831, 2012

Fear, R. C., M. Palmroth and S. E. Milan, Seasonal and clock angle control of the location of flux transfer event signatures at the magnetopause, J. Geophys. Res., 117, A04202, 2012

**Recent invited presentations:**

Fear, R. C. and L. Trenchi, Flux transfer events: Looking ahead to MMS, GEM Workshop (Plenary tutorial), Snowmass, Colorado, June 2015

Fear, R. C., S. E. Milan, J. A. Carter, R. Maggiolo, A. N. Fazakerley, I. Dandouras and S. B. Mende, Understanding the theta aurora, EGU General Assembly, Vienna, Austria, April 2015

Fear, R. C., S. E. Milan, K. Oksavik, M. Palmroth, Observational tests of flux transfer event structure, 40$^{th}$ COSPAR Scientific Assembly, Moscow, Russia, August 2014

Fear, R. C., E. J. Bunce, T. K. Yeoman, S. W. H. Cowley, A. Strømme, A. J. Kavanagh, I. W. McCrea, A. J. Coster, P. Erickson, I. Haggstrom, C. Heinselman, Ground-based support for the Juno Earth Fly-by, AGU Fall Meeting, San Francisco, USA, December 2013

## Huishan Fu

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### Education

- Bachelor degree in Physics, Yunnan Normal University, China, 2005
- PhD in Space Physics, National Space Science Center, Chinese Academy of Sciences, China, 2010

### Work Experience

- Postdoctoral researcher at Swedish Institute of Space Physics (Sweden), December 2010 – December 2012
- Professor at School of Astronautics, Beihang University (China), January 2013 – December 2015
- Professor at School of Space and Environment, Beihang University (China), January 2016 – present

### Research Interests

Fu's research is currently focusing on magnetic reconnection, dipolarization fronts, and the wave-particle interaction. In particular, he is focusing on the *in situ* observation of these processes in the Earth's magnetosphere. He has good experience in analyzing spacecraft data, particularly the data from THEMIS, Cluster, RBSP, and MMS. He proposed a new method—named as FOTE—to find magnetic nulls and reconstruct field topology (e.g., the topology of flux ropes, magnetic islands, and X-line). His previous research covers the whole magnetosphere, including foreshock, bow shock, plasmasphere, radiation belts, magnetotail, M-I coupling, and the magnetic reconnection. All the relevant work has been published in international peer-reviewed journals, presented at international conferences in both invited and solicited talks. A new manuscript related to magnetic reconnection is now submitted to international journals.

### Current projects

1) Particle energization at electron scale during magnetic reconnection.
2) Current system associated with magnetotail dipolarization fronts.
3) Formation mechanisms of magnetotail dipolarization fronts.
4) Constructing a mode for VLF waves in the Earth's radiation belts.

### Recent relevant publications

1. Fu, H. S., et al. (2016), Identifying magnetic reconnection events using the FOTE method, *J. Geophys. Res*., 121, 1263–1272.
2. Fu, H. S., et al. (2015), How to find magnetic nulls and reconstruct field topology with MMS data?, *J. Geophys. Res.,* 120, 3758–3782.
3. Fu, H. S., Y. V. Khotyaintsev, A. Vaivads, A. Retinò, and M. André (2013), Energetic electron acceleration by unsteady magnetic reconnection, *Nature Physics*, 9, 426–430.
4. Fu, H. S., et al. (2013), Dipolarization fronts as a consequence of transient reconnection: In situ evidence, Geophys. Res. Lett., 40, 6023–6027.
5. Fu, H. S., Y. V. Khotyaintsev, A. Vaivads, M. André, and S. Y. Huang (2012), Occurrence rate of earthward-propagating dipolarization fronts, Geophys. Res. Lett., 39, L10101.
6. Fu, H. S., Y. V. Khotyaintsev, A. Vaivads, M. Andre, and S. Y. Huang (2012), Electric structure of dipolarization front at sub-proton scale, Geophys. Res. Lett., 39, L06105.
7. Fu, H. S., Y. V. Khotyaintsev, M. André, and A. Vaivads (2011), Fermi and betatron acceleration of suprathermal electrons behind dipolarization fronts, Geophys. Res. Lett., 38, L16104.

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## PROFESSIONAL PREPARATION

| | | |
|---|---|---|
| Korea University, Seoul, Korea – graduated as a top graduate | Physics | B.S., 1996 |
| Korea Adv. Inst. of Sci. & Tech. (KAIST), Daejon, Korea | Space Physics | M.S., 1999 |
| Dartmouth College, Hanover, NH, USA | Space Physics | Ph.D., 2006 |

## APPOINTMENTS

NASA Goddard Space Flight Center/University of Maryland, Baltimore County, MD, USA
- MMS science using datasets and integration with simulations of magnetic reconnection
- Dayside/tail and inner-magnetospheric studies using Cluster, THEMIS, and RBSP datasets

LASP, University of Colorado, Department of Physics, CO, USA
- Vlasov and test-particle simulations for a double layer and ionospheric ion outflow
- FAST data analysis on the auroral region and Magnetosphere-Ionosphere coupling

Dartmouth College, Department of Physics and Astronomy, NH, USA
- FAST data analysis on the auroral acceleration region
- Hardware works on particle detectors of NASA's Sounding Rockets, LYNCH 30.058/059

## SYNERGISTIC ACTIVITIES

Interview with science news media
- AGU Research Spotlight by Editors, pressed in *Eos*, AGU's weekly newspaper
- ESA Cluster story and NASA Heliopress Highlights; Press releases at news media

Peer-Review Service for Spacecraft Datasets
- Cluster Active Archive (CAA, http://caa.estec.esa.int) database of four Cluster spacecraft, provided to the world-wide science community
- Developed a numerical code for FAST data, installed in FAST IDL library for public use

Referee Service
- Papers submitted to Nature Comm., JGR, Geophys. Res. Lett., Annales Geophysicae
- Proposals submitted to NASA's ROSES Heliophysics programs and NSF GEM programs

Conference/Local Meeting Service
- Panelist in 2015 KSEA (Korea-American Scientist and Engineer Associations) conference
- Convened/Convening sessions in 2014/2015 Fall AGU meeting

## SELECTED RELEVANT PUBLICATIONS


- K.-J. Hwang and D. G. Sibeck (2015), Role of Low-frequency Boundary Waves in the Dynamics of the Dayside Magnetopause and the Inner Magnetosphere, *AGU Geophysical Monograph Series*.
- K.-J. Hwang et al. (2014), A tailward-moving current-sheet-normal magnetic-field front followed by an earthward-moving dipolarization front, *J. Geophys. Res*., 119, 5316-5327.
- K.-J. Hwang et al. (2014), Wave-particle interactions during a dipolarization front event, *J. Geophys. Res*., 119, 2484-2493, doi:101002/2013JA019259.
- K.-J. Hwang et al. (2013), Cluster observations near reconnection X lines in Earth's magnetotail current sheet, *J. Geophys. Res*., 118, 4199-4209.
- K.-J. Hwang et al. (2011), Kelvin-Helmholtz waves under southward interplanetary magnetic field, ***J. Geophys. Res.***, 116, A08210, doi:10.1029/2011JA016596
- K.-J. Hwang et al. (2011), Cluster observations of multiple dipolarization fronts, ***J. Geophys. Res.***, 116, A00I32.

**Brief Curriculum Vitae for Yuri Khotyaintsev**

*Contact information:*
Dr. Yuri Khotyaintsev,
Swedish Institute of Space Physics,
Box 537, SE-75121, Uppsala, Sweden
Phone: +46-18-471-5929 (office), +46-73-6748136 (mob)
E-mail: yuri@irfu.se

*Education*:
M. Sci. in Physics, 1997, Kyiv Shevchenko University.
Ph. D. in Space Physics, 2003, Uppsala University.

*Employment*:
1998 – 2003, PhD student at Swedish Institute of Space Physics, Uppsala.
2003 – 2008, Scientist, Swedish Institute of Space Physics, Uppsala.
2008 – 2012, Research Fellow, Swedish Institute of Space Physics, Uppsala.
2012 to present, Senior Scientist, Swedish Institute of Space Physics, Uppsala.

*Experience in Space Science Missions*:
EFW instrument, Cluster, Co-Inverstigator, responsible for production of the EFW data for the CAA.
RPW, Solar Orbiter, Co-Inverstigator.
FIELDS/SDP, NASA/MMS, responsible for the SDP science data production.
RPWI, JUICE, Co-Inverstigator, responsible for coordination of data production and archiving for RPW.
EFI, THOR, PI, member of the ESA Science Study team.

*Other relevant experience*:
1999 – 2003 Development of Orbit Visualization Tool (OVT, http://ovt.irfu.se).
2005 – 2007 Member of an international team at the International Space Science Institute (ISSI) studying relationship between the reconnection and turbulence.
2008 – 2011 Team leader of an international team at ISSI "Magnetic reconnection and particle energization: synergy of in situ and remote observations", http://www.issibern.ch/teams/synergy_remote/
2012-2014, Work package leader, EU FP7 MAARBLE project, http://www.maarble.eu/project/.
2012 to present, Member of an international team ISSI studying particle acceleration at plasma jet fronts.
2015 to present, Member of an international team ISSI devoted to Cluster inner-magnetosphere campaign.
2014 to present, Member of an international team ISSI "Small Scale Structure and Transport During Magnetopause Magnetic Reconnection: from Cluster to MMS".
2015, Organizer of NORDITA program "Magnetic reconnection in plasmas", http://www.nordita.org/mrp2015
2015, Selected as Cluster Guest Investigator, with a campaign targeting bow shock at small inter-spacecraft separation, http://sci.esa.int/cluster/55616-guest-investigator-operations-2015-2016/#YKhotyaintsev
2016 to present, Member of an international team at ISSI "Particle Acceleration in Solar Flares and Terrestrial Substorms"

*Selected publications*:
• Fu, H. S., Yu. V. Khotyaintsev, A. Vaivads, A. Retinò, and M. André, Energetic electron acceleration by unsteady magnetic reconnection, *Nature Physics*, 9, 426-430, 2013.
• Khotyaintsev, Yu.V., C.M. Cully, A. Vaivads, M. André, and C. J. Owen, Plasma Jet Braking: Energy Dissipation and Non-Adiabatic Electrons, *Phys. Rev. Lett.*, 106, 165001, 2011.
• Khotyaintsev, Yu.V., A. Vaivads, M. André, M. Fujimoto, A. Retino, and C. J. Owen, Observations of slow electron holes at a magnetic reconnection site, *Phys. Rev. Lett.*, 105, 165002, 2010.
• Khotyaintsev, Yu. V., A. Vaivads, A. Retinò, M. André, C. J. Owen, H. Nilsson, Formation of Inner Structure of a Reconnection Separatrix Region, *Phys. Rev. Lett.*, Vol. 97, 205003, 2006.
• Vaivads, A., Y. Khotyaintsev, M. André, A. Retinò, S. C. Buchert, B. N. Rogers, P. Décréau, G. Paschmann, T. D. Phan, Structure of the Magnetic Reconnection Diffusion Region from Four-Spacecraft Observations, *Phys. Rev. Lett.*, Vol. 93, 105001, 2004.

Full list of publications: http://www.cluster.irfu.se/yuri/publications.html

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Celestijnenlaan 200B, 3001 Heverlee, Begium
Giovanni.lapenta@kuleuven.be; Tel. + +32 16 32 79 65

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**Professional Preparation**

| | |
|---|---|
| 1990 | Masters in Nuclear Engineering, Politecnico di Torino |
| 1993 | PhD in Plasma Physics, Politecnico di Torino |

**Appointments**

| | |
|---|---|
| 1992-1994 | Graduate Researcher, Los Alamos National Laboratory, USA |
| 1994-1996 | Post-doc scientist, Los Alamos National Laboratory, USA |
| 1995-2001 | Professor, Politecnico di Torino, Italy. |
| 1996-2006 | Staff member, Los Alamos National Laboratory, USA |
| 2006-present | Professor, University of Leuven, Belgium. |
| 2006-present | Consultant, University of Colorado, Boulder, USA. |
| 2012-present | Guest Professor, University of California, Los Angeles, USA. |
| 2005-present | Editor for EGU's Nonlinear Processes in Geophysics. |

**Honors:**

| | |
|---|---|
| 1992 | ANS "Outstanding Student Paper Award", 1992. |
| 2005 | RD100 Prize. |

**Mission Involvement**
**MMS (2002-): Co-I MMS-IDS Team of University of Colroado**

**Participation in earlier ISSI activities**
**2010-2012:** **"**Spacecraft-plasma interaction**"** **Team**
**2011-2013:** **"**Flow-driven instabilities of the Sun-Earth system**"** **Team**
**2014-2015:** **"**Slow solar wind sources andacceleration mechanisms in the corona**"** **Team**

Relevant Publications (selected from over 100 publications)

- **G. Lapenta**, Markidis, S., Goldman, M. V., & Newman, D. L. (2015). Secondary reconnection sites in reconnection-generated flux ropes and reconnection fronts. *Nature Physics*, *11*(8), 690-695.
- Vapirev, A. E., **Lapenta, G**., Divin, A., Markidis, S., Henri, P., Goldman, M., & Newman, D. (2013). Formation of a transient front structure near reconnection point in 3-D PIC simulations. *Journal of Geophysical Research: Space Physics*, *118*(4), 1435-1449.
- **G. Lapenta**, S. Markidis, S. Poedts, D. Vucinic, Space Weather Prediction and Exascale Computing, 2013, *Computing in Science & Engineering, vol. 15, p. 68.*
- T. Intrator, X. Sun, **G. Lapenta**, L. Dorf, I. Furno, Experimental onset threshold and magnetic pressure pileup for 3D Sweet-Parker reconnection, 2009, *Nature Physics, 5, 521*.
- S. Markidis, **G. Lapenta**. Rizwan-Uddin, Multi-scale simulations of plasma with iPIC3D, 2010, *Mathematics and Computers in Simulation, vol. 80, p. 1509*.
- **G. Lapenta**, J.U. Brackbill, Nonlinear Evolution of the Lower Hybrid Drift Instability: Current Sheet Thinning and Kinking, 2002, *Physics of Plasmas, vol. 9, p. 1544*.
- **G. Lapenta**, Self-feeding turbulent magnetic reconnection on macroscopic scales, 2008, *Physical review letters, vol. 100, p. 235001*.
- M. Ashour-Abdalla, **G. Lapenta**, R. J. Walker, M. El-Alaoui, & H. Liang, Multiscale Study of Electron Energization during Unsteady Reconnection Events, 2015, *Journal of Geophysical Research: Space Physics*.

**Benoit Lavraud**
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**Professional Preparation**

| | |
|---|---|
| 2000 | Masters in Astrophysics, University of Toulouse |
| 2004 | PhD in Space Plasma Physics, University of Toulouse |

**Appointments**

| | |
|---|---|
| 2004-2006 | Post-doc scientist, Los Alamos National Laboratory, USA |
| 2006-2008 | Limited-term staff member, Los Alamos National Laboratory, USA |
| 2008-present | Research scientist, Institut de Recherche en Astrophysique et Planétologie, Toulouse. |
| 2010-present | Editor for AGU's Geophysical Research Letters. |
| 2015-present | Department head "Planètes, Environnements, Plasmas Spatiaux" at IRAP. |

**Honors:**

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|---|---|
| 2002 | AGU "Outstanding Student Paper Award", 2002. |
| 2005 | ESA award "Five years of Cluster in space" for outstanding contribution. |
| 2011 | "Prime d'Excellence Scientifique" of CNRS. |

**Mission Involvement**
Cluster (2002-): CIS ion experiment Co-I
Double Star (2006-): HIA ion instrument Co-I
Solar Orbiter (2018-): SWA instrument suite Co-I
STEREO (2008-): Strong involvement (science, calibration, etc.)

**Participation in earlier ISSI activities**
2003-2005: "Outer Magnetospheric Boundaries: Cluster Results" Workshop
2004-2006: "Comparative Cluster-Double Star measurements of the dayside magnetosphere" Team
2008-2010: "Studies of dayside magnetosphere response using Cluster-THEMIS conjunctions" Team
2010-2012: "Plasma entry and transport in the plasma sheet" Team
2011-2013: "Flow-driven instabilities of the Sun-Earth system" Team

**Relevant Publications (selected from over 100 publications)**

Lavraud, B., et al., Currents and associated electron scattering and bouncing near the diffusion region at Earth's magnetopause, Geophys. Res. Lett., DOI: 10.1002/2016GL06835, 2016.

Lavraud, B., et al., Chapter 1: The magnetopause, its boundary layers, and pathways to the magnetotail, *in "The Dynamic Magnetosphere", Springer publications*, W. Liu, and M. Fujimoto (Eds), pp. 3-28, 2011.

Lavraud, B., et al., Observation of a complex solar wind reconnection exhaust from spacecraft separated by over 1800 RE, *Solar Phys*., 256, No. 1-2, p. 379-392, doi:10.1007/s11207-009-9341-x, 2009.

Lavraud, B., et al., Tracing solar wind plasma entry into the magnetosphere using ion-to-electron temperature ratio, *Geophys. Res. Lett*., 36, L18109, doi:10.1029/2009GL039442, 2009.

Lavraud, B., et al., Evidence for newly closed magnetosheath field lines at the dayside magnetopause under northward IMF, *J. Geophys. Res*., 111, No. A5, A05211, doi:10.1029/2005JA011266, 2006.

Lavraud, B., et al., Characteristics of the magnetosheath electron boundary layer under northward IMF: Implications for high-latitude reconnection, *J. Geophys. Res*., 110, A06209, doi :10.1029/2004JA010808, 2005.

Lavraud, B., et al., Cluster observations of the exterior cusp and its surrounding boundaries under northward IMF, *Geophys. Res. Lett*., 29, No. 20, 56, 2002.

David G. Sibeck

Code 674, NASA/GSFC
Greenbelt, MD 20771
1-301-286-5998 (TEL), 1-301-286-1648 (FAX)

Education: B.A. (1979), M.S. (1982), PhD. (1984) UCLA

NASA/GSFC Positions Held:

| | |
|---|---|
| 2004-2006 | LWS TR&T Project Scientist |
| 2007-present | LWS Geospace Mission Scientist |
| 2004-2007 | LWS Geospace Project Scientist |
| 2003-present | THEMIS Project Scientist |

Professional Activities:

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|---|---|
| 2015-present | President AGU SPA Section |
| 2011-2013 | Chair, NSF GEM steering committee |
| 2004-2007 | Associate Editor, GRL |
| 2004-2010 | Editorial Advisory Board, EOS |
| 2005-2010 | Guest Editor, Advances in Space Research |

Meetings Organized:

| | |
|---|---|
| 1993 | Organizer, IAGA Session on Magnetosheath |
| 1999 | Organizer, IAGA Session on Shock, Sheath, and Magnetopause |
| 2000 | Co-Organizer, NATO Magnetosheath Meeting, Antalya, Turkey |
| 2003 | Co-Organizer, IAGA Magnetopause Session, Sapporo, Japan |

**Awards**

1992 AGU Macelwane Award

Publications: 307 refereed publications (74 first-authored).

1. Sibeck, D. G., A model for the transient magnetospheric response to sudden solar wind dynamic pressure variations, J. Geophys. Res., 95, 3755, 1990.
2. Sibeck, D. G. and V. Angelopoulos, THEMIS science objectives and mission phases, Space Sci. Rev., 141, 35-89, 2008.
3. Sibeck, D. G., et al., ARTEMIS Science Objectives, Space Sci. Rev., 10.1007/s11214-011-9777-9, 2011.
4. Omidi, N., D. G. Sibeck, et al., Dynamics of the foreshock compressional boundary and its connection to foreshock cavities, J. Geophys. Res., 118, 823-831, 2013.
5. Zhang, H., D. G. Sibeck, et al., Spontaneous hot flow anomalies at quasi-parallel shocks: 1. Observations, J. Geophys. Res., 118, 3357-3363, 2012.

**Sergio Toledo-Redondo**
Science Directorate, European Space Agency, ESAC
Villanueva de la Cañada, Madrid, SPAIN.
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## PROFESSIONAL PREPARATION

| | | |
|---|---|---|
| Polytechnic University of Catalonia, Barcelona, Spain | Engineering | B.S., 2006 |
| University of Granada, Granada, Spain | Physics | M.S., 2010 |
| University of Granada, Granada, Spain | Physics | Ph.D., 2012 |

## APPOINTMENTS

Research fellow at the European Space Agency (ESA - ESAC), Villanueva de la Cañada, Madrid, Spain
- Multiple ion length-scales in magnetic reconnection: MMS and CLUSTER.

Postdoc at the Swedish Institute of Space Physics (IRF), Uppsala, Sweden
- Microphysics of magnetic reconnection using CLUSTER.

Postdoc at the University of Granada, Granada, Spain
- Ground based magnetometers for atmospheric electricity studies, Schumann resonance.

## SYNERGISTIC ACTIVITIES

Referee Service
- Papers submitted to Geophys. Res. Lett.

Conference/Local Meeting Service
- Science Organizing Committee at '4th CLUSTER-THEMIS workshop', 7-11 November 2016, Palm Spring, CA.
- Invited talk 'Energization of cold ions during magnetic reconnection at the dayside magnetopause' at AGU 14-18 December 2015, San Francisco, CA.
- Chairman at 'Magnetic Reconnection in Plasmas - NORDITA', 10-14 August 2015, Stockholm Sweden.

## SELECTED RELEVANT PUBLICATIONS

- S. Toledo-Redondo et al. (2016), Cold ion demagnetization near the X-line of magnetic reconnection, (to be submitted to) *Geophys. Res. Lett.*
- S. Toledo-Redondo et al. (2016), Cold ion heating at the dayside magnetopause during magnetic reconecction, *Geophys. Res. Lett.,* 42, 6146-6154.
- S. Toledo-Redondo et al. (2015), Modification of the Hall physics in magnetic reconnection due to cold ions at the Earth's magnetopause, *Geophys. Res. Lett.,* 43, 58-66.