ISSI Team Proposal: How does the Solar Wind Influence the Giant Planet Magnetospheres?
Team Leaders: Marissa Vogt and Adam Masters

Abstract: Our ISSI team will determine the nature of the solar wind influence on the outer planet magnetospheres. It is well established that the solar wind is the primary source of plasma in the Earth's magnetosphere and that it drives magnetic storms and substorms that lead to magnetic reconnection, plasma transport, and dazzling displays of aurora. Unlike the Earth, the magnetospheres of Jupiter and Saturn are characterized by internal sources of plasma (the moons Io and Enceladus, respectively), large spatial scales, and rapid planetary rotation. Therefore, the degree to which the solar wind influences these magnetospheres has been hotly debated, and it has been proposed that magnetospheric dynamics at Jupiter and Saturn may be driven by centrifugal stresses rather than the solar wind. Now, thanks to the existence of many relevant data sets and foundations laid by the magnetospheric science community, we are in a position to establish more definitively how the solar wind influences these giant magnetospheric systems. Our team is perfectly poised to accomplish this goal due to the inclusion of experts on both the outer planet magnetospheres and the more comprehensively studied magnetosphere of the Earth, combining experience in data analysis, theory, and modeling. We will reveal the nature of magnetopause processes, carry out a detailed examination of the magnetospheric response to varying solar wind conditions, and assess magnetotail reconnection signatures in the outer planet magnetospheres. To quantify the relative importance of the dynamic solar wind for Jovian and Saturnian magnetospheric dynamics this we will constrain the potential differences applied to each system by each mode of external solar wind driving, and compare this to the well-established potentials associated with internal driving. Our team meetings will produce collaborative research that will significantly advance understanding of solar wind-magnetosphere coupling at the outer planets.

Scientific rationale, goals, and timeliness of the project

The combination of the Galileo spacecraft's orbital tour of Jupiter, the Cassini spacecraft's ongoing exploration of Saturn, and extensive remote observations have revealed much about the magnetospheres of Jupiter and Saturn. At Jupiter, the primary source of magnetospheric plasma is, by far, the volcanic moon Io, while for Saturn the primary plasma source is the moon Enceladus. Both magnetospheres are characterized by large spatial scales and a rapid planetary rotation, which contribute to the importance of centrifugal stresses in each system. Jupiter's magnetosphere is the largest in the solar system, with a typical magnetopause standoff distance of ~60-90 R_J due to a strong planetary magnetic field and inflation by hot plasma pressure. Saturn's magnetosphere is smaller, with a subsolar standoff distance of ~25 R_S, and is often thought of as being intermediate between the terrestrial and Jovian magnetospheres. For example, Saturn's main auroral oval, like the Earth's, lies near the open/closed field line boundary [*Cowley et al.*, 2004; *Bunce et al.*, 2008], while Jupiter's main emission is associated with a system of corotation enforcement currents [e.g. *Hill*, 2001; *Cowley and Bunce*, 2001].

Despite the advances from Galileo and Cassini, our knowledge of how the Jovian and Saturnian systems work remains far from complete. For example, at the outer planets only single-spacecraft measurements are typically available, making it challenging to obtain information about the upstream solar wind conditions. Therefore, the nature of the solar wind interaction with the outer planet magnetospheres, and the importance of the solar wind relative to internal factors such as centrifugal stresses in driving dynamics, are areas of active research and debate [e.g., *McComas and Bagenal*, 2007; *Cowley et al.*, 2008; *Masters et al.*, 2014]. MHD models of solar wind properties propagated outward from 1 AU to Jupiter's orbit at ~5.2 AU or Saturn's orbit at ~9.6 AU can be used to estimate upstream solar wind measurements near the outer planets [e.g. *Tao et al.*, 2005; *Zieger and Hansen*, 2008], but these models have not been fully exploited.

The goal of our proposed ISSI team is to establish the nature of the solar wind influence on the outer planet magnetospheres. This will be accomplished through collaborative research including data analysis, theoretical studies, and numerical simulations. We will include the magnetospheres of both Jupiter and Saturn in our team activities because studies of these two rapidly-rotating magnetospheres are highly complementary. The comparative nature of our team's activities therefore increases the likelihood of success and greatly increases their scientific return.

Our team will perform specific tasks such as calculating quantities that can shed light on the importance of the solar wind interaction. For example, one can consider the ratio of the potential energy from corotation to the solar wind induced potential across the polar cap (the latter indicating the amount of energy available from the solar wind). This ratio is about 5 for the Earth, and is traditionally considered to be about 50 for Jupiter [*Khurana et al.*, 2004], which would suggest that rotational stresses are much more significant than the solar wind in driving dynamics at Jupiter. However, these numbers cited for Jupiter are based on very rough estimates, so one contribution of our team is to evaluate previous estimates of relevant reconnection voltages and other quantities based on new information from both *in situ* and remote data set and complimentary models. In addition, we will use these quantities to establish the transient magnetospheric response to changing solar wind conditions. Further description of some example team tasks is given below.

Task 1: Calculate the dayside reconnection voltage

At the Earth, the primary method by which the solar wind inputs mass and energy to the magnetosphere is through magnetic reconnection at the dayside magnetopause. The dayside reconnection voltage, which is related to the rate of magnetopause reconnection and flux opening, is a quantity that is crucial to understanding the solar wind-magnetosphere interaction. It can be calculated from the upstream solar wind properties using an empirical formula that has been successfully applied at the Earth [e.g. *Perrault and Akasofu*, 1978; *Milan*, 2004].

Reconnection efficiency can be reduced when the upstream magnetosonic Mach number and/or plasma β, the ratio of thermal to magnetic pressure, is high [*Scurry and Russell*, 1991; *Paschmann et al.*, 1986], as is the case at Jupiter and Saturn [e.g. *Masters et al.*, 2012]. Therefore, *Delamere and Bagenal* [2010] proposed that the solar wind instead interacts with Jupiter's magnetosphere not through dayside reconnection with the solar wind but through viscous processes (see Task 3). Numerical and theoretical arguments suggest that magnetopause reconnection may be unlikely at the outer planets [e.g. *Desroche et al.*, 2012, 2013], so it is therefore somewhat surprising that evidence of dayside reconnection has been observed for both Jupiter [e.g. *Walker and Russell*, 1985] and Saturn. *Bonfond et al.* [2011] reported HST observations of pulsating quasi-periodic polar auroral flares suggested to be the signature of pulsed reconnection with the solar wind. At Saturn, evidence of magnetopause reconnection has been reported in auroral images and *in situ* magnetic field and ELS measurements [*Radioti et al.*, 2011; *Badman et al.*, 2013]. However, it is noteworthy both that no flux transfer events were found in a survey of Cassini magnetometer data [*Lai et al.*, 2012; *Fuselier et al.*, 2014], and that *Masters et al.* [2012] showed that a dayside reconnection event observed by *McAndrews et al.* [2008] probably occurred during a time of unusually low b.

Our team will resolve this controversy by calculating the dayside reconnection voltage at Jupiter and Saturn. Several studies have estimated the typical dayside reconnection voltage at Jupiter and Saturn using an empirical formula [e.g. *Nichols et al.*, 2006; *Badman and Cowley*, 2007] and auroral images [e.g. *Badman et al.*, 2005], but few case studies have been performed to further constrain the reconnection rate. Additionally, the formula is sensitive to assumptions about the length of the region over which dayside reconnection can occur, which may be limited at the outer planets, and neglects any plasma β dependence of the reconnection efficiency. Our team will use *in situ* and remote auroral data, MHD models, and theoretical calculations to address these outstanding issues and calculate the dayside reconnection voltage at Jupiter and Saturn through collaborative research, including case studies of specific data and model comparisons.

Task 2: Calculate the nightside reconnection voltage and search for evidence of solar wind driving

There has been evidence of tail reconnection at Jupiter and Saturn from both *in situ* and remote auroral observations [e.g. *Russell et al.*, 1998; *Kronberg et al.*, 2005; *Vogt et al.*, 2010; *Radioti et al.*, 2008, 2011; *Hill et al.*, 2008; *Jackman et al.*, 2007; *Thomsen et al.*, 2013]. In the Earth's magnetosphere, flux that is opened via reconnection with the solar wind is closed via tail reconnection in a process called the Dungey cycle [*Dungey*, 1961]. Therefore the rate of tail flux closure, or the nightside reconnection voltage, matches the average dayside reconnection voltage. However, at the rapidly-rotating outer planets, tail reconnection may be driven by centrifugal stresses via the Vasyliunas cycle [*Vasyliunas*, 1983]. The relative roles of the Dungey and Vasyliunas cycles in driving tail reconnection at the outer planets are hotly debated [e.g., *McComas and Bagenal*, 2007; *Cowley et al.*, 2008], and our team will resolve this long-standing debate.

Studies of plasmoid signatures at both Jupiter [*Kasahara et al.*, 2013; *Vogt et al.*, 2014] and Saturn [*Jackman et al.*, 2011, 2014] have shown that reconnection at the giant planets can proceed onto lobe field lines, closing flux. These studies suggest that the nightside reconnection voltage roughly matches the dayside reconnection voltage, which could suggest that the reconnection is solar wind driven. However, the quoted values for both reconnection voltages are rough estimates that could be further constrained by additional observations and models. Our team will update the present estimates of the average nightside reconnection voltage. We will also conduct case studies comparing the nightside reconnection voltage during specific events to the dayside reconnection voltage during each event calculated (in Task 1) using solar wind conditions from a propagated MHD model. Our team will also investigate the control the solar wind exerts on the magnetotail by searching for evidence of solar wind compression-driven reconnection events, again using a propagated solar wind MHD model. We will also determine how frequently events proceed onto open field lines. These studies can be done through analysis of *in situ* and auroral data and through modeling. These studies will establish the relative roles of the solar wind and internally-driven Vasyliunas cycle in driving reconnection at the outer planets.

Task 3: Calculate the voltage associated with a viscous-like interaction

Although large-scale dayside magnetopause reconnection is the primary driver of Earth's magnetosphere, there is an additional weaker driver that nonetheless can become dominant under northward IMF (when the dayside reconnection voltage is at its lowest). This "viscous-like" driver was first discussed by *Axford and Hines* [1961]. Transfer of solar wind momentum across the magnetopause (mediated by Kelvin-Helmholtz instability and/or wave-particle interactions) leads to an effective viscous drag applied to the magnetosphere that drives system dynamics. Recent studies of the terrestrial magnetopshere have revealed more details of the mediating processes; for example, evidence for local reconnection within K-H vortices has been reported [*Hasegawa et al*., 2009]. Of more global importance, the voltage applied to Earth's magnetosphere by this viscous-like mode of interaction has been calculated to be ~20 kV [e.g., *Sundberg et al*., 2009; *Bruntz et al.*, 2012].

Delamere and Bagenal [2010] proposed that the solar wind interacts with Jupiter's magnetosphere through viscous processes, transferring momentum and possibly opening/closing magnetic flux through small-scale turbulent interaction along the magnetospheric flanks. In particular, they suggest that the primary interaction with the solar wind is through the Kelvin-Helmholtz instability, a shear flow-driven instability. These arguments can also be applied to Saturn, where Kelvin-Helmholtz vortices have been observed [*Masters et al.*, 2009, 2010; *Delamere et al.*, 2013, *Ma et al.*, 2015]. An important part of assessing how the solar wind can drive the giant planet magnetospheres is the assessment of this viscous-like interaction in the case of each system, in addition to revealing the extent of large-scale dayside and nightside reconnection (Tasks 1 and 2).

In Task 3 we will constrain the voltage applied to the magnetospheres of Jupiter and Saturn by this viscous-like interaction, establish how this voltage depends on solar wind and magnetospheric parameters, and compare the values to voltages associated with large-scale dayside reconnection (see Task 1) and internal driving. To achieve this we will examine MHD simulations of the Jovian system under a range of IMF orientations to determine the viscous-like voltage, analogous to terrestrial studies that have achieved this [*Bruntz et al.*, 2012]. In addition, we will inspect *in situ* data sets taken in the vicinity of the Jovian and Saturnian magnetopauses to calculate the speed of plasma flow in the low-latitude boundary layer. The flow speed in this layer of mixed solar wind and magnetospheric plasma immediately inside each boundary is currently the missing piece of information that we need to calculate a viscous-like voltage.

Expected Output

Our team will answer the following outstanding research questions related to the long-standing debate over the role of the solar wind in the outer planet magnetospheres:

- **How do processes like magnetic reconnection at the Jovian and Saturnian magnetopauses compare to the same processes at Earth's magnetopause?** (task 1)
- **Is reconnection with the solar wind the dominant mode of interaction, or does the viscous interaction become dominant in the outer solar system?** (tasks 1, 3)
- **If the primary method of interaction with the solar wind is a viscous process rather than dayside reconnection, how much flux can be opened/closed and mass transferred? How does this compare to mass loss/flux closure estimates from plasmoids?** (task 2, 3)
- **Is there evidence that the solar wind drives tail reconnection at Jupiter and Saturn? If so, what process (dayside reconnection, solar wind compression, or both) is responsible?** (tasks 1, 2)

We anticipate publishing at least one original peer-reviewed research paper per numbered task, and that these studies will significantly advance the present understanding of solar wind-magnetosphere coupling at the outer planets. We will identify which outstanding questions are most amenable to additional collaborative studies within the team and publish additional research results. Following both team meetings, we will write a review paper summarizing the results of our collaborations.

Added Value from ISSI

ISSI provides the perfect venue for in-depth interactions between diverse scientists to focus on the important questions raised above. The team provides a powerful combination of expertise and diversity. For example, in order to leverage present knowledge about how our own planet's magnetosphere works, our team includes experts on the terrestrial magnetosphere with a particular focus on the physical processes underpinning the interaction with the solar wind that also operate at the outer planets (e.g. magnetic reconnection, growth of the Kelvin-Helmholtz instability). Our team meetings will bring together scientists from the outer planet and terrestrial magnetosphere communities who might not otherwise have the opportunity for meaningful interaction. Our team includes data analysts, theorists, and modelers, and we have purposefully selected team members whose findings seem to be in conflict with each other (e.g., work of *Masters et al.* [2012] and *Badman et al.* [2013]). Gathering the team members at ISSI will provide a unique opportunity for thorough comparison of data and models and will also facilitate detailed, constructive discussion of contrasting results. The pooling of such knowledge and resources in the ISSI setting should enable powerful synergism in the sharing of ideas and lead to exciting new scientific results.

Timeliness of proposed team activities

Now is an ideal time for an ISSI team on the issue of solar wind-magnetosphere coupling at the outer planets, as the magnetospheric science community has now laid the necessary foundations to advance our understanding of this topic. Recent data-based and theoretical studies have provided new clues and renewed interest in this area [e.g. *Delamere and Bagenal*, 2013; *Delamere et al.*, 2013; *Desroche et al.*, 2012, 2013; *Kasahara et al.*, 2013; *Masters et al.*, 2014]. Global magnetohydrodynamic (MHD) simulations (e.g. *Chané et al.* [2013] for Jupiter and *Jia et al.* [2012] for Saturn) have reached a new level of sophistication and fidelity and can therefore be used to study the magnetospheric response to changing solar wind conditions. Our team activity is additionally timely in light of ongoing and planned spacecraft missions, including: the Cassini mission at Saturn (2004-present), JAXA's Hisaki EUV telescope (launched September 2013) that is observing Jovian aurora and the Io torus, Juno (arriving at Jupiter in 2016), and the planned ESA JUICE mission to Jupiter. We now have an extensive catalogue of auroral images of both Jupiter and Saturn from the Hubble Space Telescope, covering the full solar activity cycle. Research from this team could be used to design specific observing proposals during HST's remaining lifetime.

Confirmed Team Members

Name	Institution	Expertise (applicable to numbered tasks)
Marissa Vogt (co-team leader)	Boston University, USA	Jupiter tail reconnection; magnetometer data analysis; auroral mapping (2)
Adam Masters (co-team leader)	Imperial College, UK	Saturn magnetopause processes; Cassini data analysis (1, 3)
Sarah Badman	Lancaster University, UK	Magnetospheric and auroral dynamics (Jupiter and Saturn); *in situ* and remote data analysis (1, 2)
Bertrand Bonfond	Université de Liège, Belgium	HST auroral images, Jupiter magnetopause data analysis (1)
Emmanuel Chané	Katholieke Universiteit Leuven, Belgium	Jupiter magnetosphere MHD simulations, solar wind response (1, 2)
Peter Delamere	University of Alaska Fairbanks, USA	Magnetopause processes, data analysis, hybrid simulations (1, 3)
Hiroshi Hasegawa	JAXA, Japan	Viscous magnetopause processes at Earth (1,3)
Suzie Imber	University of Leicester, UK	Solar wind-magnetosphere coupling at Earth (1, 2)
Elena Kronberg	Max-Planck-Institut für Sonnensystemforschung, Germany	Data analysis (Galileo energetic particle detector at Jupiter and Cluster at Earth); theory (2)
Aikaterini Radioti	Université de Liège, Belgium	Auroral dynamics with HST images (Jupiter and Saturn) and Cassini UVIS (1, 2)
Chihiro Tao	Institut de Recherche en Astrophysique et Planétologie (IRAP), France	Solar wind models; magnetosphere-ionosphere-thermosphere coupling (1, 2)
Michelle Thomsen	Los Alamos National Laboratory, USA	Plasma data analysis at Earth and Saturn, Cassini CAPS instrument (1, 2)

Project Schedule

The team will hold two meetings, each lasting 5 days, in Bern, Switzerland, with the first occurring in the summer/fall of 2015. The second meeting will be held 6-12 months later.

Facilities required and financial support requested from ISSI

We request internet access, projection equipment, and meeting space for the 12 team members. We request financial support in the form of a per diem and accommodation for 12 team members during two 5-day team meetings, for a total of 120 per diems and 120 nights of accommodation. Additionally, we request support for travel costs for one of our two co-team leaders.

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Vasyliūnas, V. M. (1983), Plasma Distribution and Flow, in *Physics of the Jovian Magnetosphere*, edited by A. J. Dessler, p. 395, Cambridge Univ. Press, New York.

Vogt, M. F., M. G. Kivelson, K. K. Khurana, S. P. Joy, and R. J. Walker (2010), Reconnection and flows in the Jovian magnetotail as inferred from magnetometer observations, *J. Geophys. Res.*, doi: 10.1029/2009JA015098.

Vogt, M. F., C. M. Jackman, J. A. Slavin, E. J. Bunce, S. W. H. Cowley, M. G. Kivelson, and K. K. Khurana (2014), Structure and Statistical Properties of Plasmoids in Jupiter's Magnetotail, *J. Geophys. Res. Space Physics*, *119*, doi:10.1002/2013JA019393.

Walker, R. J. and C. T. Russell (1985), Flux Transfer Events at Jupiter, *J. Geophys. Res.*, *90*, 7397-7404.

Zieger, B. and K. C. Hansen (2008), Statistical validation of a solar wind propagation model from 1 to 10 AU, *J. Geophys. Res.*, 113, A08107, doi:10.1029/2008JA013046.

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Research Positions

April 2014 - present	*Boston University, Department of Astronomy* Postdoctoral Researcher and member of the MAVEN science team
March 2012 - March 2014	*University of Leicester – Leicester, United Kingdom* *Department of Physics and Astronomy* Research Associate in Comparative Planetary Magnetospheres

Education

2006-2012	*University of California, Los Angeles – Los Angeles, CA* Ph.D., Geophysics and Space Physics, June 2012. Thesis title: "The Structure and Dynamics of Jupiter's Magnetosphere" Advisor: Professor Margaret G. Kivelson M.S., Geophysics and Space Physics, 2009.
2002-2006	*Massachusetts Institute of Technology – Cambridge, MA* S.B. Earth, Atmospheric, and Planetary Sciences, 2006 S.B. Physics, 2006

Awards

- Prix Baron Nicolet, awarded to a distinguished researcher under the age of 40 in the field of aeronomy, from the Royal Academy of Sciences, Letters and Fine Arts of Belgium, 2012
- Outstanding Student Paper, Fall 2010 meeting of the American Geophysical Union
- Outstanding Student Paper, Fall 2008 meeting of the American Geophysical Union

Selected Publications

Vogt, M. F., M. G. Kivelson, K. K. Khurana, R. J. Walker, M. Ashour-Abdalla, and E. J. Bunce (2014), Simulating the Effect of Centrifugal Forces in Jupiter's Magnetosphere, *J. Geophys. Res. Space Physics*, doi:10.1002/2013JA019381.

Vogt, M. F., C. M. Jackman, J. A. Slavin, E. J. Bunce, S. W. H. Cowley, M. G. Kivelson, and K. K. Khurana (2014), Structure and Statistical Properties of Plasmoids in Jupiter's Magnetotail, *J. Geophys. Res. Space Physics*, *119*, doi:10.1002/2013JA019393.

Jackman, C. M., J. A. Slavin, M. G. Kivelson, D. J. Southwood, N. Achilleos, M. F. Thomsen, G. A. DiBraccio, J. P. Eastwood, M. P. Freeman, M. K. Dougherty, and **M. F. Vogt** (2014), Saturn's dynamic magnetotail: A comprehensive magnetic field and plasma survey of plasmoids and traveling compression regions, and their role in global magnetospheric dynamics, *J. Geophys. Res.*, doi:10.1002/2013JA019388.

Vogt, M. F., M. G. Kivelson, K. K. Khurana, R. J. Walker, B. Bonfond, D. Grodent, and A. Radioti (2011), Improved mapping of Jupiter's auroral features to magnetospheric sources , *J. Geophys. Res.*, *116* , A03220, doi:10.1029/2010JA016148.

Bonfond, B., **M. F. Vogt**, J.-C. Gérard, D. Grodent, A. Radioti, and V. Coumans (2011), Quasi-periodic polar flares at Jupiter: A signature of pulsed dayside reconnections?, *Geophys. Res. Lett.*, *38*, L02104, doi:10.1029/2010GL045981.

Vogt, M. F., M. G. Kivelson, K. K. Khurana, S. P. Joy, and R. J. Walker (2010), Reconnection and flows in the Jovian magnetotail as inferred from magnetometer observations, *J. Geophys. Res., 115*, A06219, doi:10.1029/2009JA015098.

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Date of birth: 18 July 1984
Nationality: British

Education

2002-2006 MSci Physics – Imperial College London. First-Class Honours.
2006-2009 PhD – Imperial College London. On the outer boundaries of Saturn's magnetosphere.

Employment

Aug-Sep 2009: Postdoctoral research associate – Imperial College London.
Oct 2009-Feb 2012: Postdoctoral research associate – Mullard Space Science Laboratory, University College London.
Mar 2012-Jun 2014: International Top Young Fellow, Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency.
Jul 2014-date: Lecturer, Planetary Physics, Imperial College London.

Research

Space plasma physics: Understanding fundamental processes and phenomena (e.g., magnetic reconnection, collisionless shocks), and revealing how different space plasma systems work (e.g., planetary magnetospheres, the heliosphere).

Mission Involvement

- *Cassini-Huygens*, mission to Saturn and Titan, in operation. Member of two Cassini instrument teams.
- *MESSENGER*, mission to Mercury, associate of the MESSENGER science team.
- *BepiColombo*, mission to Mercury, in implemetation. Mercury Magnetospheric Orbiter (MMO) science team associate.
- *Jupiter Icy Moons Explorer*, selected by ESA, Co-Investigator of the Magnetic field investigation.
- *Future mission concepts:* Small (<100 M€) CubeSat missions, large (>500 M€) missions to Uranus and Neptune.

Awards, Research Grants, and Invited Talks

- University College London Robert Boyd Award for Outstanding Scientific Achievement 2010/2011
- Japan Aerospace Exploration Agency International Top Young Fellowship, 2011, ~£230,000
- More than 20 invited talks at international meetings and research institutions

Service to the Scientific Community

- Peer reviewer for Advances in Space Research, Geophysical Research Letters, the Journal of Geophysical Research, Planetary and Space Science, the Astrophysical Journal, and NASA (funding proposals)
- Convener of 7 sessions at international meetings (most recent: EPSC 2014)
- Member of scientific organising committee, Magnetospheres of the Outer Planets Meeting, July 2013

Membership of Professional Bodies

- Fellow of the Royal Astronomical Society, 2006 to date.
- Member of the American Geophysical Union, 2007 to date.

References

Prof James Slavin, University of Michigan. Prof Masaki Fujimoto, Japan Aerospace Exploration Agency.
Dr Michelle Thomsen, Los Alamos National Laboratory. Contact details available on request.

Dr. Sarah V. Badman - Curriculum Vitae

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Email: s.badman@lancaster.ac.uk Tel: +44-1524-593417 Nationality: British

Research Positions:

Mar 2013 – present Royal Astronomical Society Research Fellow, Lancaster University (Oct 2013 - present), University of Leicester (Mar - Oct 2013), UK.

Jan 2010 – Feb 2013 JAXA International Top Young Fellow, Department of Space Plasma Physics, ISAS, Japan.

Oct 2007 – Jan 2010 Research Associate in solar-planetary physics, Radio and Space Plasma Physics Group, University of Leicester, UK.

Research Interests:

Magnetospheric and auroral dynamics in the solar system. Diagnosing the transfer of energy from the Sun to planetary environments. Use of Cassini spacecraft in situ and remote sensing data at Saturn. Interpretation and comparison of auroral emissions at ultraviolet, infrared and radio wavelengths from the outer planets.

Research Team Membership and Responsibilities

- Participating Scientist on Cassini MAG, VIMS, UVIS teams for auroral studies (2015-).
- PI of joint NOAO-HST Program GO 13035 (A unique opportunity to discover how energy is transported through Jupiter's magnetosphere, 2014) and HST Program GO 13396 (Dual views of Saturn's UV aurorae, 2014).
- Co-investigator of HST Programs GO 11984 (Observing Saturn's high latitude polar auroras, 2009), GO 12176 (Long term observations of Saturn's northern auroras, 2011-2013), GO 13012 (Near-equinox spectro-imaging of Uranus aurora sampling two planetary rotations, 2012), GO DD 14036 (Post-equinox Uranus aurorae during a strong magnetosphere-solar wind shock interaction, 2014).
- Co-investigator of several ground-based telescope proposals for observing infrared aurorae of the outer planets (Subaru, IRTF, Keck, VLT, Gemini, 2011-2014).
- Co-investigator of NIIHAMA project: Monitoring Jupiter's H3+ auroras.

Selected Publications:

- Kimura, T., **S.V. Badman**, C. Tao, K. Yoshioka, G. Murakami, A. Yamazaki, F. Tsuchiya, B. Bonfond, A. J. Steffl, A. Masters, S. Kasahara, H. Hasegawa, I. Yoshikawa, and M. Fujimoto (2015), Transient internally-driven aurora at Jupiter discovered by Hisaki and the Hubble Space Telescope, Geophys. Res. Lett., in press, doi:10.1002/2015GL063272.
- **Badman, S.V.**, G. Branduardi-Raymont, M. Galand, S.L.G. Hess, N. Krupp, L. Lamy, H. Melin, and C. Tao (2014), Auroral processes at the giant planets: energy deposition, emission mechanisms, morphology and spectra, *Space Sci. Rev,* 180, doi:10.1007/s11214-014-0042-x.
- **Badman, S.V.**, A. Masters, H. Hasegawa, M. Fujimoto, A. Radioti, D. Grodent, N. Sergis, M.K. Dougherty, and A.J. Coates (2013), Bursty magnetic reconnection at Saturn's magnetopause, *Geophys. Res. Lett.*, 40, 6, 1027-1031, doi:10.1002/grl.50199.
- Kasahara, S., E. Kronberg, N. Krupp, T. Kimura, C. Tao, **S.V. Badman**, A. Retino, M. Fujimoto (2011), Magnetic reconnection in the Jovian tail: X-line evolution and consequent plasma sheet structures, *J. Geophys. Res*, 116, A11219, doi: 10.1029/2011JA016892.
- Grocott, A., **S.V. Badman**, S.W.H. Cowley, S.E. Milan, J.D. Nichols, and T.K. Yeoman (2009), Magnetosonic Mach number dependence of the efficiency of reconnection between planetary and interplanetary magnetic fields, *J. Geophys. Res.*, 114, A07219, doi:10.1029/2009JA014330.
- **Badman, S.V.** and S.W.H. Cowley (2007), Significance of Dungey-cycle flows in Jupiter's and Saturn's magnetospheres and their identification on closed equatorial field lines, *Ann. Geophys*, 25, 941-951, doi:10.5194/angeo-25-941-2007.

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EDUCATION AND PROFESSIONAL EXPERIENCE

- Current position: Post-doctoral fellow FNRS-F.R.S.(Chargé de Recherches) - Laboratory of Planetary and Atmospheric Physics – University of Liège, Belgium.
- 03/2012 – 03/2013: Post-doctoral researcher – Southwest Research Institute, Boulder, Colorado, USA
- 02/2011 – 03/2012: Research Engineer at the Laboratory of Planetary and Atmospheric Physics – University of Liège, Belgium.
- 08/2010-02/2011: Research Scholar – Institute for Geophysics and Planetary Physics - University of California at Los Angeles, California, USA.
- 09/2009-08/2010 :Research Engineer - Laboratory of Planetary and Atmospheric Physics – University of Liège, Belgium.
- *2009 : PhD thesis – University of Liège : "Morphology and dynamics of the Io UV footprint".*
- 2007: DEA in Sciences (Space Sciences) - University of Liège - Master Thesis: "*The Io UV footprint : Analysis of Hubble Space Telescope observations of Jupiter's aurorae*"
- 2005: Engineer-Physicist - Orientation Space Techniques - University of Liège - Engineering degree thesis: "*Study of the impact of the troposphere on Galileo navigation signals*" (carried out at the European Space Agency's ESTEC facilities, Noordwijk, The Netherlands).
- Work experience: "*Maintenance operations on a sun-photometer and a micro-wave radiometer*" (carried out at the European Space Agency's ESTEC facilities, Noordwijk, The Netherlands).
- Teaching assistant in Graphical communication during the academic year 2004-2005.
- Teaching assistant in Algorithmic during the academic year 2002-2003.
- High School Degree - Athénée Royal Charles Rogier in Liège (2000) - orientation: mathematics, sciences, English and German.

SELECTED PUBLICATIONS

- Bonfond, B., Hess, S., Bagenal, F., Gérard, J.-C., Grodent, D., Radioti, A., Gustin, J., & Clarke, J. T. (2013). The multiple spots of the Ganymede auroral footprint. *Geophysical Research Letters, 40*.
- Bonfond, B., Grodent, D., Gérard, J.-C., Stallard, T., Clarke, J. T., Yoneda, M., Radioti, A., & Gustin, J. (2012). Auroral evidence of Io's control over the magnetosphere of Jupiter. *Geophysical Research Letters, 39*, 01105.
- Bonfond, B., Vogt, M. F., Gérard, J.-C., Grodent, D., Radioti, A., & Coumans, V. (2011). Quasi-periodic polar flares at Jupiter: A signature of pulsed dayside reconnections? *Geophysical Research Letters, 38*, 02104.
- Bonfond, B., D. Grodent, J. C. Gerard, A. Radioti, V. Dols, P. Delamere, and J. Clarke (2009), "The Io UV footprint: location, inter-spot distances and tail vertical extent", *J. Geophys. Res.*, , 114, A07224, doi:10.1029/2009JA014312.
- Bonfond B., D. Grodent, J.-C. Gérard , A. Radioti, J. Saur and S. Jacobsen (2008), "The UV Io footprint leading spot: A key feature for understanding the UV Io footprint multiplicity?", *Geophys. Res. Lett.*, *35*, L05107, doi:10.1029/2007GL032418.

LANGUAGES

- French : Native speaker
- English : Fluent (spoken and written)
- German : Basic

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EDUCATION:

2009 Ph.D., Centre for mathematical Plasma-Astrophysics, Katholieke Universiteit Leuven (Belgium)

2003 Master of Astrophysics and Statistical Data Analysis, University of Strasbourg (France)

RELEVANT PUBLICATIONS:

Chané, E., J. Saur, and S. Poedts, Modeling Jupiter's magnetosphere: Influence of the internal sources, accepted on 3 April 2013, *Journal of Geophysical Research*, 118, 2157-2172.

Chané, E., J. Saur, F. M. Neubauer, J. Raeder, and S. Poedts, Observational evidence of Alfvén wings at the Earth, 2012, *Journal of Geophysical Research*, 117, A09217.

Chané, E., S. Poedts, and B. van der Holst, On the combination of ACE data with numerical simulations to determine the initial characteristics of a CME, 2008, *Astron. Astrophys.*, 492, L29-L32.

Chané, E., B. van der Holst, C. Jacobs, S. Poedts, and D. Kimpe, Inverse and normal coronal mass ejections: evolution up to 1 AU, 2006, *Astron. Astrophys.*, 447, 727-733.

Chané, E., C. Jacobs, B. van der Holst, S. Poedts, and D. Kimpe, On the effect of the initial magnetic polarity and of the background wind on the evolution of CME shocks, 2005, *Astron. Astrophys.*, 432, 331-339.

AWARDS AND HONORS:

AGU Outstanding Student Paper Award 2009 for the presentation of: "Global MHD simulations of Jupiter's magnetosphere: study of the Ionosphere-Magnetosphere coupling"

Dr. Peter A. Delamere: Curriculum Vitae

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Dr. P. A. Delamere is an Associate Professor of Space Physics at the University of Alaska Fairbanks. His research focuses on comparative magnetospheric physics with an emphasis on the numerical simulation of space plasmas using hybrid (kinetic ion, fluid electron) and multi-fluid techniques. Dr. Delamere has studied the solar wind interaction with the giant magnetospheres of Jupiter and Saturn, comets, Pluto, and the plasma interaction at Io. In addition, he has developed models to study the flow of mass and energy through the magnetospheres of Jupiter and Saturn to study the internally-driven dynamics of these systems.

Education and Degrees Earned

June 1991: B.A. in Physics from Carleton College (*cum laude*), Northfield, MN

May 1998: Ph.D. in Physics at University of Alaska Fairbanks, Fairbanks, AK

Professional Experience

Oct 2012 - present: Associate Professor of Space Physics at University of Alaska Fairbanks.

Nov 2001 - Oct 2012: Research Associate at Laboratory for Atmospheric and Space Physics, University of Colorado.

Jan 2000 - Oct 2001: Senior Research Associate at Atmospheric and Environmental Research Inc., Lexing- ton, MA, studying plasma dynamics in the Io plasma torus.

May 1998 - Dec 1999: Post Doctoral Fellow at Geophysical Institute, University of Alaska Fairbanks, studying active plasma experiments.

Professional Organizations

Member, American Geophysical Union since 1992.

Selected Publications

Delamere, P. A., *Magnetotails in the Solar System*, chap. Solar wind interaction with the giant magneto- spheres and Earth's magnetosphere, ISBN: 978-1-118-84234-8, Wiley: AGU Geophysical Monograph Series, 2015.

Delamere, P. A., F. Bagenal, C. Paranicas, A. Masters, A. Radioti, B. Bonfond, L. Ray, X. Jia, J. Nichols, and C. Arridge, Solar Wind and Internally Driven Dynamics: Influences on Magnetodiscs and Auroral Responses, *Space Sci. Rev.*, doi10.1007/s11214-014-0075-1, 2014.

Delamere, P. A., and F. Bagenal, Magnetotail structure of the giant magnetospheres: Implications of the viscous interaction with the solar wind, *Journal of Geophysical Research (Space Physics)*, *118*, 7045– 7053, doi10.1002/2013JA019179, 2013.

Delamere, P. A., R. J. Wilson, S. Eriksson, and F. Bagenal, Magnetic signatures of Kelvin-Helmholtz vor- tices on Saturn's magnetopause: Global survey, *Journal of Geophysical Research (Space Physics)*, *118*, 393–404, doi10.1029/2012JA018197, 2013.

Delamere, P. A., Auroral signatures of solar wind interaction at Jupiter, *AGU Geophysical Monograph Series: "Auroral Phenomenology and Magnetospheric Processes: Earth and Other Planets"*, 197, 2012.

Hiroshi Hasegawa

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Education
1997 B.S. in Physics, Nagoya University, Japan
1999 M.S. in Particle and Astrophysical Sciences, Nagoya University, Japan
2002 Ph.D. in Particle and Astrophysical Sciences, Nagoya University, Japan

Career Summary
1999-2002 Research Fellow (DC) of JSPS, Nagoya University, Japan
2002-2005 Research Associate, Thayer School of Engineering, Dartmouth College, USA
2005 Research Fellow (PD) of JSPS, Tokyo Institute of Technology, Japan
2006-2007 Research Associate, Institute of Space and Astronautical Science, JAXA, Japan
2007-present Assistant Professor, Institute of Space and Astronautical Science, JAXA, Japan

Honors/Awards
AGU Outstanding Student Paper Award (1999 AGU Fall Meeting, SPA Section)
AGU Editor's Citation for Excellence in Refereeing (2007, 2012 Geophysical Research Letters)
AGU Editor's Citation for Excellence in Refereeing (2008 Journal of Geophysical Research-Space Physics)
The 32th SGEPSS Obayashi Award (September 2009, 126th SGEPSS meeting)

Research Topics
(1) Plasma transport across the magnetopause using data from magnetospheric satellite missions
(2) Reconstruction of space plasma structures in space-time from in situ measurements

Recent Invited Presentations
Hasegawa, H., Multi-spacecraft observations of solar wind-magnetosphere interactions, *IAU (International Astronomical Union) XXVIII General Assembly*, Beijing, August 2012.
Hasegawa, H., A. Masters, T. K. M. Nakamura, and T. Sundberg, Kelvin-Helmholtz instability at planetary magnetopauses: an overview and comparison, *Chapman Conference on Fundamental Properties and Processes of Magnetotails*, Reykjavik, March 2013.

Selected Publications
Hasegawa, H., M. Fujimoto, T.-D. Phan, H. Rème, A. Balogh, M. W. Dunlop, C. Hashimoto, and R. TanDokoro, Transport of solar wind into Earth's magnetosphere through rolled-up Kelvin-Helmholtz vortices, *Nature*, *430*, 755-758, 2004.
Hasegawa, H., B. U. Ö. Sonnerup, M. Fujimoto, Y. Saito, and T. Mukai, Recovery of streamline in the flank low-latitude boundary layer, *J. Geophys. Res.*, *112*, A04213, doi:10.1029/2006JA012101, 2007.
Hasegawa, H., Structure and dynamics of the magnetopause and its boundary layers, *Monographs on Environment, Earth and Planets (MEEP)*, 1(2), 71-119, doi:10.5047/meep.2012.00102.0071, 2012.
Hasegawa, H., H. Zhang, Y. Lin, B. U. Ö. Sonnerup, S. J. Schwartz, B. Lavraud, and Q. G. Zong, Magnetic flux rope formation within a magnetosheath hot flow anomaly, *J. Geophys. Res.*, *117*, A09214, doi:10.1029/2012JA017920, 2012.

Suzanne M. Imber

Contact details	Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH Tel: 0116 223 1302 Email: s.imber@ion.le.ac.uk	

Research Interests	Solar wind-magnetosphere-ionosphere coupling at Earth Location and rate of reconnection in Earth's magnetotail Reconnection and dynamics at Mercury	
Employment History	Lecturer and Leverhulme Research Fellow (from 1st March) Radio & Space Plasma Physics Group, University of Leicester	2014-
	Visiting Scientist, AOSS, University of Michigan	2011-
	Postdoctoral Research Associate Radio & Space Plasma Physics Group, University of Leicester	2011-14
	Postdoctoral Research Associate NASA Goddard Space Flight Centre	2008-11
Education	Doctor of Philosophy (Ph.D.) Space plasma physics University of Leicester	2005-08
	Master in Science (M.Sci.), Physics, First Class Honours Imperial College, London	2001-05
Community Activities	Reviewer for NASA and NSF proposals from the GEM and base programmes	2011-
	Reviewer for major journals in the field, including the *Journal of Geophysical Research* and *Annales Geophysicae*	2009-
Conference Organisation	Co-convenor, Terrestrial and planetary magnetotails, EGU Co-convenor, Planetary Space Weather, EPSC	2011&12 2013

Selected Publications

Imber SM, SE Milan, and M Lester**,** Solar cycle variations in polar cap area measured by the SuperDARN radars, J. Geophys. Res. Space Physics, 118, doi:10.1002/jgra.50509, 2013.

Slavin, J. A., **Imber, S. M** et al., MESSENGER observations of a flux-transfer-event shower at Mercury, *J. Geophys. Res.*, 117, A00M06, doi:10.1029/2012JA017926, 2012.

Imber, S. M., J. A. Slavin, H. U. Auster, and V. Angelopoulos, A THEMIS survey of flux ropes and traveling compression regions: Location of the near-Earth reconnection site during solar minimum, *J. Geophys. Res.*, 116, A02201, doi:10.1029/2010JA016026, 2011.

Imber, S. M., Milan, S. E. and Hubert, B., The auroral and ionospheric flow signatures of dual lobe reconnection, *Annales Geophysicae*, vol. 24, no11, pp. 3115-3129, 2006.

Elena A. Kronberg

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Research Interests

Dynamics of the terrestrial magnetosphere: the ion composition in the Earth's magnetosphere, the region upstream to the Earth's bow shock; dynamics of the Jovian magnetotail: energetic particle observations

Employment

Max-Planck Institute for Solar System Research	Staff scientist	since November 2006
Max-Planck Institute for Solar System Research	Postdoc	May - October 2006
Altai State University	Teaching assistant	September 2001- December 2002

Education

Technical University of Braunschweig/ Max-Planck Institute for Solar System Research	PhD: "Dynamics of the Jovian magnetotail"	2003-2006
Altai State University	Master in physics with Honor	2001

Space Missions Involvement

- The Cluster/RAPID Co-Investigator
- Cluster Active Archive assistant, RAPID data calibration and analysis
- Galileo data analysis

Publications

32 peer reviewed publications

Selected peer reviewed publications

Field-aligned beams and reconnection in the Jovian magnetotail, **Kronberg, E. A.**, S. Kasahara, N. Krupp and J. Woch, Icarus, 217, pp. 55-65, doi:10.1016/j.icarus.2011.10.011, 2012

A summary of observational records on periodicities above the rotational period in the Jovian magnetosphere, **Kronberg, E. A.**, J. Woch, N. Krupp and A. Lagg, Ann. Geophys., 27, 2565-2573, 2009

Mass-release in the Jovian magnetosphere: Statistics on particle burst parameters, **Kronberg, E. A.**, J. Woch, N. Krupp, A. Lagg, , J. Geophys. Res., 113, A10202, doi:10.1029/2008JA013332, 2008.

Comparison of periodic substorms at Jupiter and Earth, **Kronberg, E. A.**, J. Woch, N. Krupp, A. Lagg, P. W. Daly, and A. Korth , J. Geophys. Res., 113, A04212, doi:10.1029/2007JA012880, 2008.

A possible intrinsic mechanism for the quasi-periodic dynamics of the Jovian magnetosphere, **Kronberg E. A.**, K-H. Glassmeier, J. Woch, N. Krupp, A. Lagg and M. K. Dougherty, J. Geophys. Res., 112 (A5), A05203, doi:10.1029/2006JA011994, 2007.

Mass release at Jupiter - substorm-like processes in the Jovian magnetotail, **Kronberg, E. A.**, J. Woch, N. Krupp, A. Lagg, K. K. Khurana, and K-H. Glassmeier, J. Geophys. Res., 110, A03211, 2005.

Name: Dr Aikaterini Radioti

Education:
2003-2006: PhD., Max-Planck-Institute for Solar System Research, Katlenburg-Lindau and Technical University of Braunschweig, Braunschweig, Germany
2006 (4 months): Research Fellow, Max-Planck- for Solar System Research, Katlenburg-Lindau, Germany
2006-now: Research Fellow, University of Liège, Liège, Belgium

Current position: Post-Doc Researcher, Laboratory for Planetary and Atmospheric Physics, University of Liège, Liège, Belgium

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Scientific interests: UV auroral emissions at Jupiter and Saturn, ionospheric-magnetospheric coupling, magnetopause reconnection, tail reconnection and dynamics, plasma acceleration

Space Missions: Member of the scientific team associated with the UVIS instrument on board Cassini. Co-I of HST Jupiter's and Saturn's campaigns. Co-Investigator of the UVS Science team onboard JUNO.

Awards:
1) Prix des Amis de l'ULg, University of Liege, Belgium, 2014
2) Arne Richter Award for Outstanding Young Scientists' (Union Medal) of the European Geosciences Union, 2012
3) Prix Baron Nicolet' of the Royal Academy of Sciences, Belgium, 2010

Relevant Publications:

Radioti, A., D. Grodent, J.-C. Gérard, S. E. Milan, R.C. Fear, C.M. Jackman, B. Bonfond, W. Pryor and J. Gustin, Saturn's elusive nightside polar arc, Geophys. Res. Lett., doi:10.1002/2014GL061081.

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Curriculum Vitae

(Last updated: March 6, 2015)

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Educational Background

Apr. 2000–Mar. 2004 Undergraduate student at Tohoku University

Apr. 2004–Mar. 2006 Master course at Department of Geophysics, Tohoku University

Apr. 2006–Mar. 2009 Ph.D. course at Department of Geophysics, Tohoku University (supervisors: Prof. Hiroshi Fukunishi and Prof. Yasumasa Kasaba)

Ph.D. degree (passed on March 25, 2009) Thesis title: "Numerical Studies of Jupiter's Magnetosphere-Ionosphere -Thermosphere Coupling Current System"

Professional Experience

Apr. 2009–Mar. 2010 JST/CREST (Prof. Takashi Tanaka) Postdoc researcher at Tohoku Univ.

Apr. 2010–Dec. 2012 Project researcher at Japan Aerospace Exploration Agency

Apr.–Oct. 2012 Part-time lecturer for physical mathematics exercise class at Rikkyo Univ.

Jan.–Dec.2013 Postdoc researcher at Laboratoire de Physique des Plasmas, Ecole Polytechnique

Jan. 2014 – JSPS Postdoctoral Fellow for Research Abroad at IRAP

Research Interests/Experiences

・Response of the Jovian magnetosphere to the solar wind

・Jovian magnetosphere-ionosphere-thermosphere coupling system: aurora generation and angular momentum transfer

・Comparative multi-wavelength aurora of the giant planets: Jupiter, Saturn, and beyond

・Data assimilation of the solar wind

Publication Related to the ISSI Team

・I developed solar wind model to predict its variations at Jupiter [Tao et al., 2005] and Saturn etc., and applied to investigations of solar wind-magnetosphere interaction [Tao et al., 2005; Kimura et al., 2013, in press, Tao et al., under preparations].

・I investigated Jupiter's magnetotail using Galileo magnetometer data [Tao et al., 2005, in press].

Tao, C., F. Sahraoui, D. Fontaine, J. de Patoul, T. Chust, S. Kasahara, and A. Retino, Properties of Jupiter's magnetospheric turbulence observed by the Galileo spacecraft, J. Geophys. Res. Space Physics, in press.

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Michelle Thomsen is a Senior Scientist at the Planetary Science Institute and a Retired Fellow of the Los Alamos National Laboratory. She received her Ph.D. in physics from the University of Iowa in 1977 and was a staff scientist at Los Alamos from 1981 until her retirement in 2009. Her primary area of expertise is the magnetospheres of the Earth and other planets and their interactions with the solar wind. Her research activities have involved the analysis and interpretation of spacecraft data, especially plasma data from the ISEE satellites, the Cassini spacecraft to Saturn, and the Los Alamos geosynchronous satellites, and she is the author or co-author of over 400 publications. Until her retirement, she was the principal investigator for the plasma instruments on the geosynchronous satellites. She is a co-investigator on the Cassini/CAPS research team. She was elected a Fellow of the American Geophysical Union in 2001. She has served on a number of committees and advisory and review panels for NASA, NSF, the NRC, and the American Geophysical Union. She recently chaired the panel on Solar Wind Magnetosphere Interactions, one of three disciplinary panels convened by the NRC to prepare the just-released United States Decadal Survey for Solar and Space Physics.

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Gosling, J. T., M. F. Thomsen, S. J. Bame, R. C. Elphic, and C. T. Russell, Plasma Flow Reversals at the Dayside Magnetopause and the Origin of Asymmetric Polar Cap Convection, *J. Geophys. Res.*, *95*, 8073, 1990.

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