Resolving the Microphysics of Collisionless Shock Waves

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2018 ISSI Team Proposal Call
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Abstract: *We propose a Space Sciences team to the International Space Science Institute (ISSI) to take advantage of the current, unprecedented temporal, angular, and energy resolution measurements from the THEMIS, Magnetospheric Multiscale (MMS), and* Wind *missions to conduct focused research on collisionless shock waves. The motivation for the proposed effort derives from several key unresolved questions about the microphysical processes that regulate the dynamics of collisionless shock waves. Despite years of investigation the relative importance of quasi-static vs. high frequency electromagnetic fluctuations is not well established, the generation mechanisms and mutual interactions of several ion foreshock phenomena are not well understood, and the partition of energy among the components, including both thermal and non-thermal/accelerated populations of different particle species, lacks any quantitative understanding. We will prioritize the outstanding questions that can be addressed by a focused effort and resolve those issues in the proposed collaboration. The proposed effort will primarily draw on on bow shock observations by MMS but will coordinate with THEMIS and* Wind *observations. Complementary state of the art multi-dimensional, kinetic, numerical simulations will provide exploration of the context and detailed microphysical processes at work. Our team is comprised of the top shock researchers, in both data analysis and simulation, from three European nations, the United States, and Japan.*

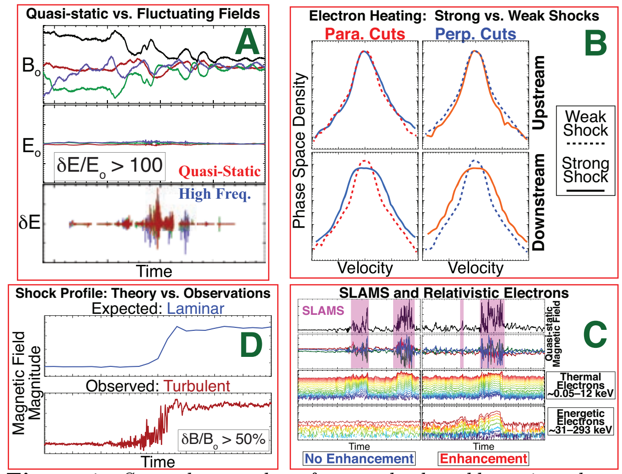

Figure 1: *Several examples of unresolved problems in collisionless shock physics, where the panels are as follows:* ***A*** *example showing $\delta E \gg E_o$ (adapted from Wilson III et al. [2014a,b]);* ***B*** *shows energy-dependent differences in electron heating between typical weak and strong shocks;* ***C*** *shows groups of SLAMS without and with relativistic electron enhancements (adapted from Wilson III et al. [2016]); and* ***D*** *compares the theoretical prediction with observations of the magnetic profile of a weak, quasi-perpendicular shock (adapted from Wilson III et al. [2017]).*

1 Science

1.1 Science Questions and Goals

Science Questions

We propose to examine the microphysical processes of collisionless shocks using spacecraft data in conjunction with kinetic simulations to prioritize and then address these central science questions:

1. **How do foreshock disturbances locally accelerate particles?**
2. **How is energy partitioned between electron and ion distributions at shocks?**
3. **What role do fluctuating fields play in particle dynamics?**

1.2 Scientific Motivation

Background Collisionless shock waves are an ubiquitous phenomena throughout the universe from interplanetary shocks driven by coronal mass ejections through planetary bow shocks driven by magnetized obstacles to astrophysical shocks driven by supernova explosions [e.g., see *Balogh and Treumann*, 2013; *Burgess and Scholer*, 2013; *Burgess et al.*, 2012; *Caprioli et al.*, 2010; *Parks et al.*, 2017; *Treumann*, 2009; *Wilson III*, 2016; *Wilson III et al.*, 2017, and references therein]. The evolution, propagation, and thickness of the shock ramp – the spatial gradient scale length of the magnetic transition region – are thought to depend upon the upstream fast mode Mach number, M_f, shock normal angle, θ_{Bn} – the angle between the average upstream quasi-static magnetic field, $\mathbf{B}_{o,up}$, and the shock normal vector, $\hat{\mathbf{n}}$ – and the average upstream plasma beta, β_{up} – ratio of thermal to magnetic energy density [e.g., see *Burgess et al.*, 2016; *Krasnoselskikh et al.*, 2013; *Treumann*, 2009, and references therein]. Heliospheric collisionless shocks are then categorized as quasi-perpendicular(quasi-parallel), $\theta_{Bn} \geq 45°(\theta_{Bn} < 45°)$; low(high) Mach number, $M_f \lesssim 2.5(M_f > 2.5)$; and low(high) beta shocks, $\beta_{up} \leq 0.5$–$1.0(\beta_{up} > 1.0)$ [e.g., see *Burgess et al.*, 2016; *Krasnoselskikh et al.*, 2013; *Lembège et al.*, 2004; *Parks et al.*, 2017; *Treumann*, 2009, and references therein]. Astrophysical collisionless shocks can have the additional complication of being relativistic versus non-relativistic [e.g., *Marcowith et al.*, 2016].

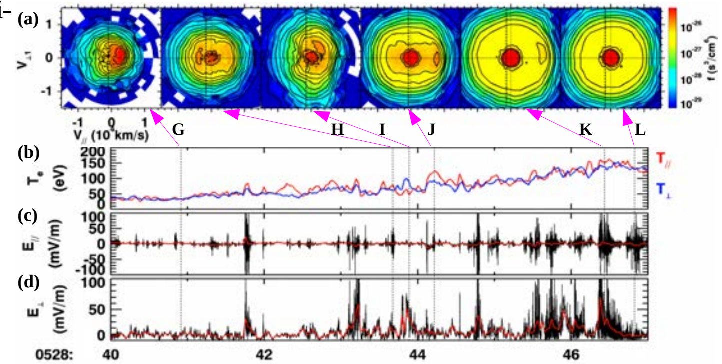

Figure 2: *An example bow shock crossing observed by the MMS mission [Burch et al., 2016] illustrating the unprecedented high resolution data available. The panels are as follows: (a) shows 2D slices of six example electron velocity distributions [from >200 during the shown period] in units of phase space density [# s^{+3} cm^{-6}]; (b) the parallel (red line) and perpendicular (blue line) electron temperature [eV]; (c) parallel electric field (black line) and median filter (red line) [mV/m]; and (d) perpendicular electric field magnitude (black line) and median filter (red line) [mV/m] (adapted from Chen et al. [2018]).*

Dissipation Mechanisms The purpose of these categorizations lies in the different predicted energy dissipation mechanisms – the processes by which the shock converts bulk flow kinetic energy into other forms like heating and/or accelerating particles. The dominant mechanisms are still a matter of debate. Some studies focused on quasi-static fields [e.g., *Dimmock et al.*, 2012; *Schwartz et al.*, 2011], others on dispersive radiation [e.g., *Dimmock et al.*, 2013; *Sundkvist et al.*, 2012], particle reflection/acceleration[1] [e.g., *Burgess and Scholer*, 2013; *Burgess et al.*, 2012; *Caprioli et al.*, 2015], and still others suggest the above processes generate conditions conducive for high frequency waves which ultimately dissipate energy [e.g., *Wilson III et al.*, 2014a,b].

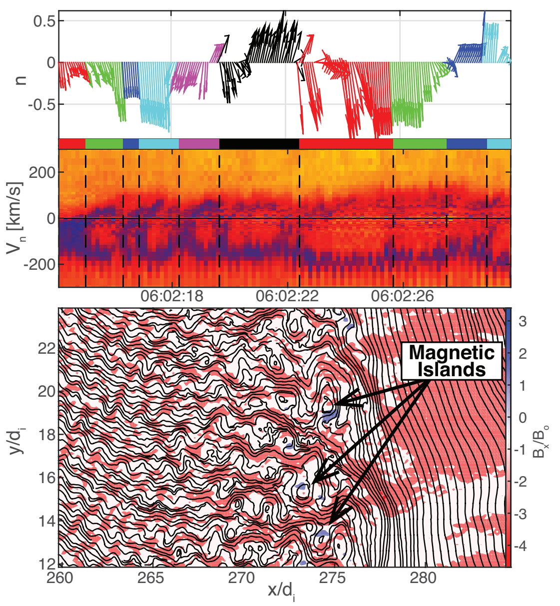

Figure 3: *MMS observations of quasi-periodic oscillations in the shock normal vector (top), ion phase space holes (middle) due to the transverse propagation of ripples along the shock surface, and supporting kinetic simulations (bottom) showing the formation of magnetic turbulence and islands that reconnect within the shock layer itself. Studies that are only possible with MMS will investigate these very localized processes (adapted from Gingell et al. [2017]).*

Unknowns Despite decades of observation, theory, and simulation work, the fundamental processes that regulate collisionless shocks are still poorly understood. For instance, the terrestrial bow shock and associated ion foreshock have received a great deal of attention but researchers continue to make unexpected discoveries, e.g., the existence of foreshock bubbles [e.g., *Turner et al.*, 2013], local generation of field-aligned ion beams by short, large-amplitude magnetic structures (SLAMS) [e.g., *Wilson III et al.*, 2013], local acceleration of electrons from thermal to relativistic energies [e.g., *Wilson III et al.*, 2016], shock ripples [e.g., *Gingell et al.*, 2017; *Johlander et al.*, 2016], ubiquity of nonlinear whistlers even at weak shocks [e.g., *Wilson III et al.*, 2017], etc.

Instrument Advances: Particles Some of the major limitations in early observations resulted from low time resolution data which prevented researchers from examining small-scale shock-related phenomena, thus limiting the analysis to large-scale, fluid-like phenomena (e.g., that low Mach number, low beta, quasi-perpendicular shocks have laminar, step-like magnetic field profiles). Figures 2 and 4 provide perfect examples of the improved capabilities offered by the MMS spacecraft. Figure 2 shows roughly six seconds of a bow shock crossing with a *small selection* of electron velocity distributions shown from FPI [*Pollock et al.*, 2016]. We emphasize the number of distributions here because all previous missions would, at best, have only two full 3D electron velocity distributions during this period, i.e., only two contour plots and two points in the temperature plot

[1] typically specific to quasi-parallel and/or high Mach number shocks

(panel b) as compared with the 200 returned by each MMS spacecraft. Figure 4 similarly shows the vastly improved temporal resolution over previous missions, where prior work would have been limited to one velocity distribution, MMS can measure over 100 during this interval. To illustrate this point more clearly, never before has a spacecraft measured electron velocity fluctuations within a magnetosonic-whistler precursor, as is shown in Figure 4.

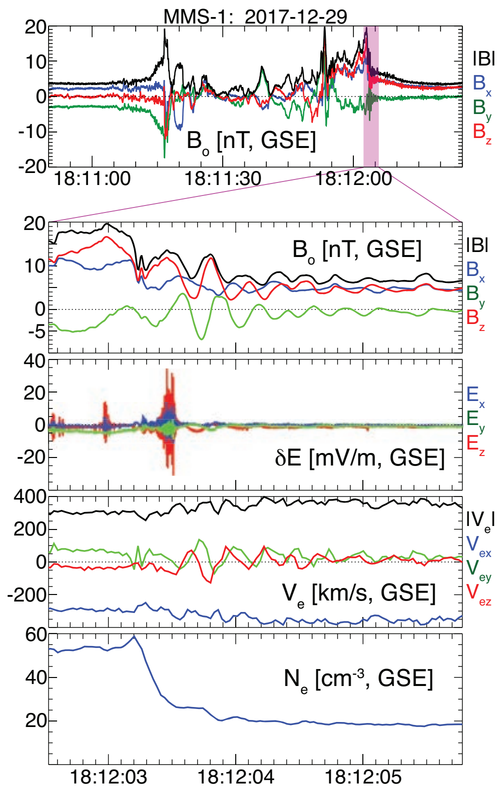

Figure 4: *Example of an HFA observed by MMS to illustrate the high cadence of the data. In the bottom zoom-in, there would be at most one full 3D velocity distributions from any previous mission but MMS returned ∼100 (adapted from Turner et al. [2018]).*

Early work found that the temperature from total electron distribution velocity moments depended upon macroscopic parameters like M_f. More recent work examined the full 3D velocity distributions which started to reveal evidence that, for instance, the electron heating at shocks is energy-dependent (e.g., see Figures 1 and 2). That is, the low energy electrons behave differently than the high energy electrons across a shock even though the temperature derived from the entire distribution seems to respond consistent with earlier observations [e.g., *Wilson III et al.*, 2009, 2010, and references therein]. Perhaps more importantly, the evolution of the electron distributions through the shock are extremely complicated (e.g., see Figure 2) [e.g., *Chen et al.*, 2018], suggesting that one needs to examine much more than just the temperature. To add further complications to the issue, the ions can also exhibit very complicated behavior as evidenced by the shock ripples observed by MMS (e.g., see Figure 3) [e.g., *Gingell et al.*, 2017; *Johlander et al.*, 2016].

Instrument Advances: Fields The lack of high resolution electric field time series led many studies to conclude that the amplitudes of the high frequency electrostatic waves within shocks were not large enough to regulate the shock dynamics. These studies relied upon time- and frequency-averaged dynamic spectra data, which has been shown to underestimate the instantaneous wave fields by upwards of two orders of magnitude [e.g., *Wilson III et al.*, 2011, and references therein]. The reality is that the high, not low, frequency components of the electric field dominate over the quasi-static fields by several orders of magnitude (e.g., see Figures 1, 2, and 4) [e.g., *Chen et al.*, 2018; *Wilson III et al.*, 2014a,b]. Further, the magnetic fluctuations were under-resolved in earlier work as well since recent studies have found electromagnetic waves well beyond nonlinear thresholds even at weak shocks[2] (e.g., see Figure 1) [e.g., *Chen et al.*, 2018; *Wilson III et al.*, 2017]. Although the fields measured by MMS are not necessarily unique in their high time resolution[3], the accuracy and duration of the three electric and magnetic field components as provided by the FIELDS instrument suite on MMS [*Torbert et al.*, 2016] are unprecedented. **We will use the combination of enhanced particle and field measurements from MMS to bring closure on the topics of the partition of energy among the particle distributions and the relevance of fluctuating fields within the shock.**

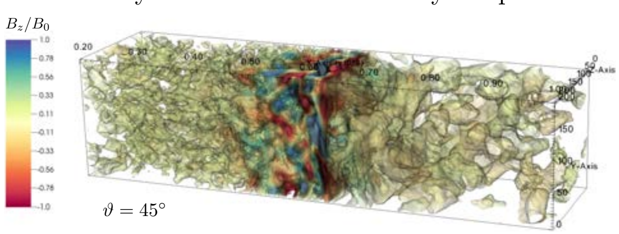

Figure 5: *3D Hybrid simulations showing self-generated electromagnetic fluctuations due to the interaction between the incident flow and the ions reflected and accelerated by the shock. The panel shows an example with $\theta_{Bn} \sim 45°$ (adapted from Caprioli and Spitkovsky [2014]).*

Local Acceleration The recent discovery that one type (i.e., SLAMS) of the nonlinear, transient waves and structures (*foreshock disturbances* for brevity) in the terrestrial foreshock are capable of locally generating strong field-aligned ion beams much like the bow shock was a complete surprise [*Wilson III et al.*, 2013]. Further examination found that many

[2] typical observations can exhibit $\delta B/B_o \gtrsim 1$, thus the shocks are not laminar

[3] *Wind* had two components at 120,000 samples/s for a ∼17 ms waveform capture and STEREO had three at up to 250,000 samples/s for a ∼65 ms waveform capture

of these foreshock disturbances can locally generate their own mini-foreshocks [*Liu et al.*, 2016]. Later that year, relativistic electrons were observed within multiple types of foreshock disturbances and it was found that the thermal electrons were being locally accelerated to relativistic energies by something within the foreshock disturbances [*Wilson III et al.*, 2016]. A statistical study found that ∼30% of all foreshock disturbances generate >25 keV electrons [*Liu et al.*, 2017]. However, none of the energetic electron observations can be explained with the standard shock acceleration models and the data are not consistent with magnetospheric leakage or a solar source. All of these recent observations have raised more questions than they answered and provoked a renewed interest in collisionless shock research. **For the first time since the dawn of the space age, it is now possible to observe electron and ion heating in combination with microphysical processes occurring in collisionless shocks, allowing us to reach closure on the source of particle energization at the bow shock and within foreshock disturbances.**

Simulations One of the biggest limitations in early simulation work was computational power leading to unrealistically small ion-to-electron and plasma-to-cyclotron frequency ratios and/or small simulation domains and/or reduced dimensions. Simulations are starting to show evidence of the small-scale, variable nature of collisionless shocks. Hybrid simulations have taken advantage of improved computational resources (e.g., see Figures 3 and 5) by increasing the simulation domains and spatial dimensions from 1D to 2D, 2.5D, and 3D [e.g., *Burgess et al.*, 2016; *Caprioli and Spitkovsky*, 2014; *Caprioli et al.*, 2015; *Gingell et al.*, 2017; *Hao et al.*, 2016, 2017; *Karimabadi et al.*, 2014]. PIC simulation studies are also taking advantage of more powerful computers by increasing the mass ratio (e.g., $M_i/m_e \sim$ 400–1836) [e.g., *Guo et al.*, 2017; *Marghitu et al.*, 2017; *Matsukiyo and Matsumoto*, 2015; *Muschietti and Lembège*, 2013, 2017] and the plasma-to-cyclotron frequency ratio (e.g., $\omega_{pe}/\Omega_{ce} \sim$ 8–10) [e.g., *Marghitu et al.*, 2017; *Muschietti and Lembège*, 2013, 2017]. **In summary, advances in computational power and simulation techniques, combined with the 100s of MMS bow shock crossings, make the timeliness of this proposal ideal. We will use the high resolution MMS observations examined by our ISSI team to define challenges for simulations to address in order to bring closure to our prioritized science questions.**

2 Relevance, Timeliness, and Team

2.1 Relevance to ISSI

The proposed effort will consist of a team of international scientists for supported research following the requirements and guidelines of the International Space Science Institute (ISSI). The team (see the roster in Section 2.3 and attached CVs for each member) consists of the leading experts in the physics of collisionless shocks, from instrumentation/data analysis to kinetic simulations. Furthermore, several of the team members have active roles on each of the key missions or are experts with their simulation code. Thus, this proposal is directly relevant to ISSI, whose mission defines it as "an Institute of Advanced Study where scientists from all over the world meet in a multi- and interdisciplinary setting to... contribute to the achievement of a deeper understanding of the results from different space missions [and] ground based observations... through multidisciplinary research in the framework of International Teams." This proposal falls under Space Sciences, specifically heliospheric and astrophysical shocks. Our team is comprised of the top shock researchers, in both data analysis and simulation, from three European nations, the United States, and Japan, ISSI is a unique opportunity and Bern an ideal forum to conduct the proposed research.

2.2 Timeliness of Proposed Study

Studying collisionless shock waves using MMS is an important and timely topic because:

1. the mission has already accumulated hundreds of shock crossings;
    (a) the MMS spacecraft has unprecedented resolution;
    (b) multi-spacecraft studies using MMS and THEMIS can constrain spatial scales;
    (c) multi-spacecraft studies can also distinguish local vs. remote processes;
    (d) *Wind* and ARTEMIS can examine lower Mach number interplanetary shocks;
2. shocks are ubiquitous but the fundamental processes are still poorly understood;
3. our results will improve the science return of future missions (e.g., *Solar Orbiter*); and
4. the fundamental energy dissipation mechanisms are universal for all plasmas.

We expect that this ISSI team will make significant advancements in the understanding of the microphysics of collisionless shocks. Our minimum success criterion will be at least two refereed publications per year, but we expect several more will result from this unique collaboration. Further, we will present our results at international conferences like AGU Fall Meeting, EGU General Assembly, AOGS Meeting, SHINE, etc. In all publications, whether refereed or conference presentation, we will acknowledge ISSI support. The final results will be summarized in a review paper submitted to the ISSI Space Science Editor at the conclusion of the effort.

2.3 ISSI Team

Name	Affiliation	Expertise and Missions
Lynn B. Wilson III	NASA, USA	Field and Particle Data Analysis
Team Leader		*Wind*, THEMIS, and MMS
	Team Members	
Ivan Vasko	Space Sciences Laboratory, USA	Theory, Field, and Particle Data Analysis
	University of California, Berkeley	THEMIS and MMS
Li-Jen Chen	NASA, USA	Field and Particle Data Analysis
	University of Maryland	MMS
Katherine Goodrich	LASP, USA	Field and Particle Data Analysis
	University of Colorado, Boulder	MMS
Steven J. Schwartz	LASP, USA	Theory and Particle Data Analysis
	Imperial College, London, UK	MMS
Drew L. Turner	Aerospace Corp., USA	Energetic Particle Data Analysis
		THEMIS and MMS
Adnane Osmane	Aalto University, Finland	Theory and Numerical Simulation
Damiano Caprioli	University of Chicago, USA	Hybrid and PIC Simulation
		Astrophysical Plasmas
Bertrand Lembege	LATMOS CNRS, France	Hybrid and PIC Simulation
		Heliospheric & Astrophysical Plasmas
David Burgess	Queen Mary University, London, UK	Hybrid and PIC Simulation
		Heliospheric Plasmas
Masahiro Hoshino	University of Tokyo, Tokyo, Japan	Hybrid and PIC Simulation
		Heliospheric & Astrophysical Plasmas
Imogen L. Gingell	Imperial College, London, UK	Hybrid and PIC Simulation

3 Schedule

We propose two team meetings in Bern, Switzerland in 2018 and 2019. The first meeting will identify critical elements within the science questions in Section 1.1, initiate the working collaborations between observation and simulations/theory, and then designate work tasks. The first meeting will also serve as a critical interface between the experimental and simulation researchers so as to focus our attention on the problems that are currently accessible with modern computational resources. Note that the accessibility of the datasets will allow for real-time investigations. The time between the first and second meeting will allow for sufficient time to research, analyze, and publish results relating to the top prioritized science questions. We will have monthly telecons to maintain momentum and boost collaboration. During the second meeting each working group from the prior year will highlight their new results. We will determine whether further investigations are necessary or if the work led to new discoveries. Again, we will focus our efforts by designating tasks to the working groups to maximize the scientific output of our team. There is already a sufficient shock event list to accomplish the goals of this proposal, thus the timing is perfect for our proposed effort.

4 Budget and Facilities

Budget: We request financial support for the following expenses for each of the two one-week meetings in Bern, Switzerland:

1. Living expenses in Bern for the 11 team members, with no funding required for the team leader;
2. Travel funding for one team member (TBD) to/from each team meeting;
3. If selected, we will also use an additional 20% of the budget for young researcher participation

Facilities: For both meetings, we will require a meeting room with projection capabilities and seating space for up to 20 people. The room arrangements should allow for people to work comfortably on laptop computers. We will also require internet access and a sufficient number of power outlets in the meeting room and would greatly appreciate access to spare electrical adaptors.

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Curriculum Vitae

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B.A. (Physics) May 2005	Saint John's University, Collegeville, MN

Professional Experience

Civil Servant (Permanent Appt.), 2010 – Present	NASA Goddard Space Flight Center
Project Scientist, 2016 – Present	*Wind* spacecraft
Deputy Project Scientist, 2012 – 2016	*Wind* spacecraft
Research Fellow, Sep. 2007 – Sep. 2010	University of Minnesota, Minneapolis, MN

Honors, Awards, & Grants

Awards

Mar. 2017	2016 Editors' Citation for Excellence in Refereeing – JGR

Successful Proposals

Mar. 2016 – Feb. 2019	2015 ROSES HSR Solicitation (PI)
Mar. 2016 – Feb. 2019	2015 ROSES HSR Solicitation (Co-I)
Jan. 2015 – Dec. 2016	2014 ROSES HGI ODDE Solicitation (Co-I)
Oct. 2015 – Sep. 2016	2015 NASA Science Innovation Fund Solicitation (Co-I)

Scholarships & Fellowships

May 2010 – Sep. 2010	Dr. Leonard F. Burlaga/Arctowski Medal Fellowship
Sep. 2007 – May 2010	NASA Earth and Space Science Fellowship, Heliophysics Division

Professional Societies

American Geophysical Union	Member: 2006 – Present
European Geosciences Union	Member: 2011 – Present
American Physical Society	Member: 2011 – Present
American Institute Of Aeronautics & Astronautics	Member: 2016 – Present

Community Service

Convener, 2017 AGU Fall Meeting	Session: "Collisionless Shock Waves in Astrophysical Plasmas"
Convener, 2016 AGU Fall Meeting	Session: "Collisionless Shock Waves in Astrophysical Plasmas"
Committee Member, 2015	Strategic Planning Committee, Heliophysics Science Division
Convener, 2014 AGU Fall Meeting	Session: "Twenty years of Wind observations"
Convener, 2012 AGU Fall Meeting	Session: "Wave-Particle Interactions and Collisionless Shocks"
Referee, 2011 – Present	*Nature*, *Astrophys. J.*, *Space Sci. Rev.*, *Geophys. Res. Lett.*, *Phys. Plasmas*, *J. Geophys. Res.*, *Rev. Modern Plasma Phys.*, *Planet. Space Sci.*, *J. Plasma Phys.*, *Ann. Geophys.*, & *Adv. Space Res.*

Selected Publications

Wilson III, L.B., *et al.*, *Phys. Rev. Lett.* **99**(4), 041101, 10.1103/PhysRevLett.99.041101, 2007.
Wilson III, L.B., *et al.*, *J. Geophys. Res.* **114**, A10106, 10.1029/2009JA014376, 2009.
Wilson III, L.B., *et al.*, *Geophys. Res. Lett.* **38**, L17107, 10.1029/2011GL048671, 2011.
Wilson III, L.B., *et al.*, *Geophys. Res. Lett.* **39**, L08109, 10.1029/2012GL051581, 2012.
Wilson III, L.B., *et al.*, *J. Geophys. Res.* **118**, 5–16, 10.1029/2012JA018167, 2013a.
Wilson III, L.B., *et al.*, *J. Geophys. Res.* **118**, 957–966, 10.1029/2012JA018186, 2013b.
Wilson III, L.B., *et al.*, *J. Geophys. Res.* **119**, 6455–6474, 10.1002/2014JA019929, 2014a.
Wilson III, L.B., *et al.*, *J. Geophys. Res.* **119**, 6475–6495, 10.1002/2014JA019930, 2014b.
Wilson III, L.B., *Geophys. Monogr. Ser.* **216**, 269–291,10.1002/9781119055006.ch16, 2016.
Wilson III, L.B., *et al.*, *Phys. Rev. Lett.* **117**(21), 215101, 10.1103/PhysRevLett.117.215101, 2016.
Wilson III, L.B., *et al., J. Geophys. Res.*, **122**(9), 9115–9133, 10.1002/2017JA024352, 2017.

Co- Investigator: Ivan Vasko
Assistant Researcher
UC Berkeley, Space Sciences Laboratory,7 Gauss Way, Berkeley, California 94720
Telephone: (510) 642-0549, E-mail: ivan.vasko@ssl.berkeley.edu

Passport name spelling: Ivan Vasko

Professional Preparation

Moscow State University (Russia), Department of Physics; Degree & Year: M.S. in Physics, 2011
Space Research Institute, Russian Academy of Science; Degree & Year: Ph.D. in Theoretical Physics, 2014

Appointments

2018 Jan–present: Assistant Researcher at Space Sciences Laboratory, University of California, Berkeley, USA
2016 Sep –2017 Dec: Post-doc at Space Sciences Laboratory, University of California, Berkeley, USA
2015 (June-Sept): Visitor at the Warwick University, Warwick, UK
2013 – 2016: Junior Research Fellow at Space Research Institute, RAS, Moscow, Russia
2011 – 2013: Engineer at Space Research Institute, RAS, Moscow, Russia

Research Experience: Spacecraft data analysis: observations of current sheets by multispacecraft (Cluster) and single spacecraft (Geotail, Venus Express, Galileo) missions in the Earth, Venus and Jupiter magnetospheres and comparison with theoretical models; Modelling nonlinear and solitary waves in space plasma; Resonant charged particle scattering and acceleration in the inner magnetosphere: wave-particle nonlinear interaction and quasi-linear theory; Development and application of Vlasov code simulations in space plasma; analysis of electric field measurements across shock waves using Magnetospheric Multiscale spacecraft data.

Publications, Awards, and Professional Service: Dr. Vasko is the first author of 21 and co-author of 23 scientific publications (current citation index is 283; full list of publications can be found at Google Scholar Citations https://scholar.google.com/citations). Dr. Vasko is a reviewer (2014-present) for *J. Geophys. Res.*, *Geophys. Res. Lett.* and *Physics of Plasmas*. He is also mentoring summer students in UC Berkeley.

Selected Publications

Vasko I.Y., O.V. Agapitov, F.S. Mozer, A.V. Artemyev and J. Drake (2017), Electron holes in inhomogeneous magnetic field: Electron heating and electron hole evolution, *Physics of Plasmas*, v.23. doi: 10.1063/1.4950834

Vasko I.Y., O.V. Agapitov , F.S. Mozer, A.V. Artemyev, J. Drake and I.V. Kuzichev (2017), Electron holes in the outer radiation belt: characteristics and their role in electron energization, *J. Geophys. Res.*, doi: 10.1002/2016JA023083

Vasko I.Y., O. Agapitov, F. Mozer , A. Artemyev, V. Krasnoselskikh and J. Bonnell (2017), Diffusive scattering of electrons by electron holes around injection fronts, *J. Geophys. Res.*, doi: 10.1002/2016JA023337

Vasko I.Y., O.Agapitov, F. Mozer, J. Bonnell, A. Artemyev, V. Krasnoselskikh, G. Reeves and G. Hospodarsky (2017), Electron-acoustic solitons and double layers in the inner magnetosphere, *Geophys. Res. Lett.*, doi: 10.1002/2017GL074026

Li-Jen Chen Associate Research Scientist, Department of Astronomy, UMD/GSFC

Professional Preparation

2002	Ph.D.	Physics	University of Washington
1997	M.S.	Physics	University of Washington
1993	B.S. with distinction	Physics	National Taiwan University

Positions Held

2014-present	Associate Research Scientist	University of Maryland/Goddard Space Flight Center
2013-2014	Associate Research Professor	University of New Hampshire
2008-2013	Assistant Research Professor	University of New Hampshire
2005-2007	Research Scientist III	Space Science Center, University of New Hampshire
2004-2005	Assistant Research Scientist	Department of Physics and Astronomy, University of Iowa

Experiences:

Li-Jen has served as the Principal Investigator and co-Investigator for projects integrating theories, simulations, space measurements, and laboratory experiments to study the nonlinear physics of collisionless plasmas. Her research expertise include: Electron heating, ion thermalization and reflection at collisionless shocks; Structure and dynamics of the diffusion region in collisionless magnetic reconnection and the associated plasma heating and particle acceleration; Electrostatic solitary waves in thin current layers in planetary magnetospheres, interplanetary space, and the laboratory; Analytical theory of solitary waves and double layers.

Selected publications:

Electron acceleration and thermalization at Earths quasi-perpendicular bow shock, L.-J. Chen, et al., *Phys. Rev. Lett.*, 2018, under review.

The electron diffusion during magnetopause reconnection with an intermediate guide field: Magnetospheric Multiscale observations, L.-J. Chen, et al., *J. Geophys. Res.*, 122, 52355246, 2017.

Drift Waves, Intense Parallel Electric Fields, and Turbulence Associated with Asymmetric Reconnection at the Magnetopause, R. Ergun, L.-J. Chen, et al., *Geophys. Res. Lett.*, 44, 2978, 2017.

Parallel electron heating in the magnetospheric inflow region, S. Wang, L.-J. Chen, et al., *Geophys. Res. Lett.*, 44, 4384, 2017.

Electron energization and mixing observed by MMS in the vicinity of an electron diffusion region during magnetopause reconnection, L.-J. Chen, et al., *Geophys. Res. Lett.*, 43, 6036, 2016.

Electron energization and structure of the diffusion region during asymmetric reconnection, L.-J. Chen, et al., *Geophys. Res. Lett.*, 43, 2405, 2016.

The inversion layer of electric fields and electron phase-space-hole structure during 2D collisionless magnetic reconnection, L.-J. Chen, et al., Phys. Plasmas, 18, 012904, 2011.

Observation of energetic electrons within magnetic islands, L.-J. Chen, et al., *Nature Phys.*, 4, 19, 2008.

Electrostatic solitary structures observed at Saturn, J. D. Williams, L.-J. Chen, et al., *Geophys. Res. Lett.*, 33, L06103, doi:10.1029/2005GL024532, 2006.

On the width-amplitude inequality of electron phase space holes, L.-J. Chen, et al., *J. Geophys. Res.*, 110, A09211, doi:10.1029/2005JA011087, 2005.

Electrostatic solitary structures associated with the November 10, 2003 interplanetary shock at 8.7 AU, J. D. Williams, L.-J. Chen, et al., *Geophys. Res. Lett.*, 32, L17103, 2005.

Bernstein-Greene-Kruskal solitary waves in three-dimensional magnetized plasma, L.-J. Chen, D. J. Thouless, and J.-M. Tang, *Phys. Rev.* E, 69, 055401(R), 2004.

BGK electron solitary waves in 3D magnetized plasma, L.-J. Chen and G. K. Parks, *Geophys. Res. Lett.*, 29(9), 1331, 2002.

Katherine Goodrich

KG

Phone: +1-978-505-1421 • E-Mail: Katherine.goodrich@lasp.colorado.edu

Experience

Post-doctoral Researcher **Jun 2017 – Present**
University of Colorado Boulder, Department of Astrophysical and Planetary Sciences and
Laboratory of Atmospheric and Space Physics
Boulder, Colorado, United States
Advisor: Dr. Robert Ergun
Responsibilities: MMS FIELDS team member and data analysis.

Graduate Research Assistant **Aug. 2011 – May 2017**
University of Colorado Boulder, Department of Astrophysical and Planetary Sciences and
Laboratory of Atmospheric and Space Physics
Boulder, Colorado, United States
Advisor: Dr. Robert Ergun
Responsibilities: MMS FIELDS team member and data analysis.

Post-baccalaureate Researcher **June 2010 – Aug. 2011**
Los Alamos National Laboratory, Space Science and Applications Group
Los Alamos, New Mexico, United States
Advisors: Dr. Ruth Skoug and Dr. John Steinberg
Responsibilities: Data analysis using data from the Ulysses mission and assisted in pre-launch instrumentation calibration for the Van Allen Probes mission.

Education

University of Colorado at Boulder **Aug. 2011 – May 2017**
Department: Astrophysical and Planetary Sciences
Degree: Doctor of Philosophy
Thesis: *Kinetic Electric Field Signatures Associated with Magnetic Turbulence and Their Impact on Space Plasma Environments*
Master of Science
Advisor: Dr. Robert Ergun

Boston University **Sept. 2006 – May 2010**
Department: Physics
Degree: Bachelor of the Arts

Invited Presentations

- **2016 American Geophysical Union: "**Classifying Large-Amplitude Parallel Electric Fields Along the Magnetopause and Their Effect on Magnetic Reconnection"
  - Received *Outstanding Student Presentation Award*
- **2017 American Geophysical Union:** "The Generation and Micro-scale Effects of Electrostatic Waves Observed in an Oblique Shock"

Steven Jay Schwartz
March 2018

Laboratory for Space Physics, University of Colorado Boulder
3665 Discovery Drive, UCB 600, Boulder 80303, CO, USA
Tel: +1 303-735-5536 Mob: +1 720-975-3555 Email: steven.schwartz@lasp.colorado.edu

FURTHER EDUCATION

1969-1973	Cornell University, Ithaca, NY , B.Sc. Engineering Physics
1973-1977	Cambridge University, Cambridge, UK, PhD. Applied Math & Th Physics

DISTINCTIONS

1972	Tau Beta Pi National Science and Engineering Honorary Society
1973-76	Winston Churchill Scholar, Churchill College, Cambridge
1982-83	Nuffield Foundation Science Research Fellow
2006	Chapman Medal of the Royal Astronomical Society
2015-2016	Leverhulme Trust Research Fellow
2017	Institute of Physics Cecilia Payne Gaposchkin Medal and Prize

APPOINTMENTS

1979-1994	Lecturer, then Reader, School of Math Sciences, Queen Mary College
1994-2004	Professor of Space Plasma Physics, Queen Mary, University of London
2005-	Professor of Space Physics, Imperial College London
2009-2013	Head, Space & Atmospheric Physics, Imperial College London
2013-2017	Director, Imperial Space Lab
2018-	Res. Assoc., LASP; Distinguished Res Fell (Emeritus) Imperial College London

RESEARCH HIGHLIGHTS and INTERESTS

- Combined theoretical, observational and simulational attack on collisionless shocks such as the Earth's bow shock. Highlights include the discovery of Hot Flow Anomalies and study of other upstream phenomena (energetic ions, Short large Amplitude Magnetic Strucrues), studies of electron heating and dynamics, and studies of magnetosheath waves/mirror modes.
- Unique studies identifying **slow mode shocks**, as predicted by magnetic reconnection theory, in the deep geomagnetic tail.
- First direct measurement of the propagation of a crack in the surface of a neutron star during a **magnetar** "star-quake" through novel use of the Cluster electron data.
- Co Investigator: AMPTE UKS; Cluster PEACE, Data System; MMS

SELECTED RECENT PUBLICATIONS (from ~ 170)

- I Gingell, S. J. Schwartz, D. Burgess, .. K Goodrich, et al., MMS Observations and Hybrid Simulations of Surface Ripples at a Marginally Quasi-Parallel Shock. *JGR*, 122:11, 2017.
- A Johlander, S. J. Schwartz, I. Gingell, et al. Rippled quasi-perpendicular shock observed by the Magnetospheric Multiscale spacecraft. *PRL*, 117(16):165101
- S. J. Schwartz, E. G. Zweibel, and M. Goldman. Microphysics in Astrophysical Plasmas, in *Microphysics of Cosmic Plasmas*, ISSI. In A. Balogh, A. Bykov, P. Cargill, R. Dendy, T. Dudok de Wit, and J. Raymond, editors, Microphysics of Cosmic Plasmas, p5. 2014.
- J. J. Mitchell and S. J. Schwartz. Isothermal magnetosheath electrons due to nonlocal electron cross talk. *JGR*, 119:1080–1093, 2014
- V. See, R. F. Cameron, and S. J. Schwartz. Non-adiabatic electron behaviour due to short-scale electric field structures at collisionless shock waves. *Ann. Geophys.*, 31:639–646, 2013.
- Masters, L. Stawarz, M. Fujimoto, S. J. Schwartz, et al., Electron acceleration to relativistic energies at a strong quasi-parallel shock wave. Nature Physics, 9:164–167, 2013.
- S. J. Schwartz, E. Henley, J. Mitchell, and V. Krasnoselskikh. Electron Temperature Gradient Scale at Collisionless Shocks. *PRL*, 107(21):215002, 2011.

DREW L. TURNER Co-Investigator

Member of the Technical Staff, Space Sciences Department, The Aerospace Corporation, Los Angeles, CA

EDUCATION

University of Colorado at Boulder (CU): Ph.D. in Aerospace Engineering Sciences; 2010
M.S. in Aerospace Engineering Sciences; 2008

Embry-Riddle Aeronautical University (ERAU), B.S. in Engineering Physics; Minor in Mathematics; 2005

PROFESSIONAL POSITIONS AND EXPERIENCE

Member of the Technical Staff: Data analysis and instrument development, The Aerospace Corporation, Sep. 2014 - present

Associate Researcher: Calibration of the THEMIS-SST instruments, data analysis of outer radiation belt electrons and foreshock phenomena at Earth, UCLA, Jan. 2011 – Jun. 2014 as Assistant Researcher, Jul. 2014 – Sep. 2014 as Associate Researcher

Graduate Research Assistant: Data analysis to study Earth's outer radiation belt electrons, Laboratory for Atmospheric and Space Physics, CU, Jul. 2006 – Dec. 2010.

PROFESSIONAL ACHIEVEMENTS AND AWARDS

2016 – Recipient of the COSPAR Zeldovich medal for excellence and achievement as an early-career scientist

RECENT PUBLICATIONS

1. **Turner, D. L.**, et al. (2017), Examining coherency scales, substructure, and propagation of whistler-mode chorus elements with Magnetospheric Multiscale (MMS), *JGR, 122,* doi:10.1002/2017JA024474.
2. **Turner, D. L.**, et al. (2017), Multipoint observations of energetic particle injections and substorm activity during a conjunction between Magnetospheric Multiscale (MMS) and Van Allen Probes, *JGR, 122*, doi:10.1002/2017JA024554.
3. **Turner, D. L.,** et al. (2016), Energy limits of electron acceleration in the plasma sheet during substorms: A case study with the Magnetospheric Multiscale (MMS) mission, *GRL., 43*, doi:10.1002/2016GL069691.
4. **Turner, D. L.,** et al. (2015), The effects of geomagnetic storms on electrons in Earth's radiation belts, *GRL, 42*, doi:10.1002/2015GL064747.
5. **Turner, D. L.,** et al. (2015), Energetic electron injections deep into the inner magnetosphere associated with substorm activity, *GRL, 42,* doi:10.1002/2015GL063225.
6. **Turner, D. L.,** et al. (2014), On the cause and extent of outer radiation belt losses during the 30 September 2012 dropout event, *JGR, 119*, doi:10.1002/2013JA019446.
7. **Turner, D. L.,** et al. (2014), Competing source and loss mechanisms due to wave-particle interactions in Earth's outer radiation belt during the 30 September to 3 October 2012 geomagnetic storm, *JGR*, *119*, doi:10.1002/2014JA019770.
8. **Turner, D. L.,** et al. (2013), On the storm-time evolution of relativistic electron phase space density in Earth's outer radiation belt, *JGR, 118*, doi:10.1002/jgra.50151.
9. **Turner, D. L.,** Y. Shprits, M. Hartinger, and V. Angelopoulos (2012), Explaining sudden losses of outer radiation belt electrons during geomagnetic storms, *Nature Physics*, *8*, doi:10.1038/NPHYS2185.

CURRICULUM VITAE

1. BASIC INFORMATION

FULL NAME, DATE OF BIRTH AND CITIZENSHIP

- Osmane, Adnane
- 28 July 1984
- Canadian

PRESENT EMPLOYMENT AND POSITION TITLE

- School of Electrical Engineering, Aalto University, Finland
  Academy of Finland Postdoctoral Fellow
- Rudolf Peierls Centre of Theoretical Physics, University of Oxford, UK
  Visiting Postdoctoral Fellow

EDUCATION AND DEGREES AWARDED

- PhD, Physics, University of New Brunswick, Canada, October 2013
- M.Sc., Physics, University of New Brunswick, Canada, September 2009
- B.Sc. Physics, Université de Montréal, Canada, January 2007

2. QUALIFICATIONS IN RESEARCH AND DOCTORAL TRAINING

MAJOR AWARDS AND FELLOWSHIPS BY SCIENTIFIC SOCIETIES AND ACADEMIC INSTITUTIONS

- Magnus Ehrnrooth Foundation Grants, Finland, 2500€
- Academy of Finland Postdoctoral Fellowship, 225 925€
- Natural Sciences and Engineering Research Council of Canada Doctoral Fellowship, 63 000$CAD
- University of New Brunswick Board of Governors Graduate Award, 7500$CAD

NATURE AND SCOPE OF PUBLICATIONS

- Primary expertise in modelling wave-particle interactions of thermal and energetic (i.e. relativistic) electrons in planetary radiation belts.
- Secondary expertise in kinetic instabilities of weakly collisional plasmas and information theoretic approaches (permutation entropy and Jensen-Shannon complexity measure) to data analysis.
- Publications in space plasma physics covering topics relating to solar wind, collisionless shocks, magnetosheath, radiation belts and space weather using a combination of theoretical models, numerical tools and *in situ* data.

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Damiano Caprioli

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University of Chicago
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http://www.astro.uchicago.edu/~caprioli

ACADEMIC TRAINING

Scuola Normale Superiore, Pisa, Italy
Ph.D. in Physics with honors, 2009
M.A. in Physics with honors, 2005

Pisa University, Pisa, Italy
M.A. in Physical and Astrophysical Sciences with honors, 2005
B.S. in Physical and Astrophysical Sciences with honors, 2003

RESEARCH INTERESTS

Kinetic theory and simulation of astrophysical plasmas; Origin and propagation of cosmic rays; Phenomenology of supernova remnants, pulsars, and galaxy clusters; Shocks and energetic particles in the heliosphere; Cosmic ray feedback in galaxy formation and dynamics; Laboratory plasmas

RESEARCH EXPERIENCE

Assistant Professor **2016–**
Department of Astronomy and Astrophysics – The University of Chicago
Postdoctoral Research Assistant/ Associate Research Scholar **2011–2016**
Department of Astrophysical Sciences – Princeton University

Postdoctoral Research Assistant **2009–2011**
INAF – Arcetri Observatory, Florence, Italy

Doctoral Candidate **2005–2009**
Scuola Normale Superiore di Pisa, Italy; *Advisors*: Prof. Mario Vietri and Prof. Pasquale Blasi; *Thesis*: *Non-linear cosmic ray acceleration in supernova remnants*

Undergraduate Research Assistant **2003–2005**
Scuola Normale Superiore di Pisa / Pisa University, Italy
Advisor: Prof. Mario Vietri; *Thesis*: *On pulsar electrodynamics*

ACTIVITIES FOR THE SCIENTIFIC COMMUNITY

Referee for Science, Nature, Nature Astronomy, PRL, PRD, PRE, ApJ, JGR, MNRAS, A&A, APh, JCAP, EPJ, PASJ, PPCF, Ap&SS, NJP, JPP.

Reviewer for NASA, NSF, Netherlands Organisation for Scientific Research (NWO), German Academic Exchange Service (DAAD), and German Israeli Foundation (GIF).

FIVE RELEVANT PUBLICATIONS

D. Caprioli, D. T. Yi, A. Spitkovsky, *Chemical Enhancements in Shock-accelerated Particles: Ab-initio Simulations*, *PRL* **119** (Oct. 2017), 171101 [arXiv:1704.08252]

J. Park, **D. Caprioli** and A. Spitkovsky, *Simultaneous Acceleration of Protons and Electrons at Nonrelativistic Quasiparallel Collisionless Shocks*, *Phys. Rev. Lett.* **114** (Feb., 2015), 085003 [arXiv:1412.0672]

D. Caprioli, A.-R. Pop and A. Spitkovsky, *Simulations and Theory of Ion Injection at Non-relativistic Collisionless Shocks*, *ApJ Letters* **798** (Jan., 2015) L28 [arXiv:1409.8291]

D. Caprioli and A. Spitkovsky, *Simulations of ion acceleration at non-relativistic shocks. III. Particle diffusion*, *ApJ* **794** (Sep., 2014) 47, [arXiv:1407.2261].

D. Caprioli and A. Spitkovsky, *Simulations of ion acceleration at non-relativistic shocks. II. Magnetic field amplification*, *ApJ* **794** (Sep., 2014) 46 [arXiv:1401.7679].

D. Caprioli and A. Spitkovsky, *Simulations of ion acceleration at non-relativistic shocks. I. Acceleration efficiency*, *ApJ* **783** (Mar., 2014) 91, [arXiv:1310.2943].

Curriculum vitae

Name: LEMBEGE ; Firstname: Bertrand ; Nationality: French
Address: LATMOS-IPSL-CNRS, Quartier des Garennes, 11 Boulevard d'Alembert,
78280 Guyancourt ; FRANCE
Phone: +33 1 80 28 50 70 Fax: +33 1 80 28 52 97
Present position : Directeur de Recherches Emerite at CNRS .
E-mail: bertrand.lembege@latmos.ipsl.fr

Education:

June 1976: **PhD Thesis** in Plasma Physics, Theoretical Group of Prof. Pellat, at Ecole Polytechnique (Palaiseau).
September 1976-December 1978: Research Fellow at the ESTEC Center (ESA), Noordwijk, The Netherlands.
January 1979: Research Physicist position at Centre National de la Recherche Scientifique (CNRS, France).
February 1982: **State Thesis** in Astrophysics, (Paris VII University).

Expertise:

A) Theoretical research (1976-1982) : Two-dimensional Tearing mode instability and magnetic reconnection

B) Experimental, theoretical, and modeling research (1978-1983) : Properties of Electron cyclotron harmonic waves (ECHW). Evidence and comparative analysis in space /laboratory experiments, theory and modelings.

C) Numerical simulations (since April 1982) :

- Dynamics of collisionless shocks : particle acceleration and heating; sources of shock front nonstationarity (coupling of macro- and micro-turbulence processes), impact of this turbulence to particle energization (electrons, pick-up ions and heavy ions). Application to quasi-perpendicular, quasi-parallel shocks, and full ion/electron foreshocks. Application to CLUSTER/MMS mission data analysis, to solar shocks, planetary shocks, astrophysics and to the heliospheric terminal shock.
- "Colliding" of two collisionless shock : impact on the shock front turbulence
- "Global" 3D-PIC simulation of the solar wind-terrestrial magnetosphere interaction:
- Large scale 3D-PIC simulations of LMA (Lunar Magnetic Anomalies).

Honors :

International Oscar Buneman Award: Oct 2009

Services in National and/or International Committees

1988–2000: Expert-Advicer at the Commissariat à Energie Atomique (CEA) for Fusion Plasma
1993–2000: Elected co-Chairman of the URSI-France Council (commission H for CNFRS)
2000–2001: Chairman of ISSI networks
2005–2014: Elected member of the European Physical Society (Plasma Physics division)
2010–Present: Member of the steering committee of the EQUIPEX named DIGISCOPE
2008–Present: Co-chairman of sessions at COSPAR
2008–Present: Co-chairman of the International Working Group "Computer Simulations in Space Plasmas for commission H of URSI.
2007–Present: Chairman and Co-chairman of sessions regularly organized at AOGS every year
2002–Present: Chairman of sessions regularly organized at URSI every three years
1987–Present: Chairman/Co-chairman of International Schools for Space Simulations series (ISSS) regularly organized every 2-3 years. The next one will be organized at UCLA (CA, USA) in August 2018.
1991–2013: Chairman and main organizer of several "European Workshops on Collisionless shocks" (EWCS) organized in Paris.

Selected pubications :

Muschietti, L. and B. Lembège "Two-stream instabilities from the lower-hybrid to the electron cyclotron frequency: application to the front of quasi-perpendicular shocks," *Annales Geophysicae* **35**, pp. 1093-1112, doi :10.519/angeo-35-1093-2017, 2017.

Pogorelov N.V., ..., B. Lembège, et al., "Heliosheath Processes and the Structure of the Heliopause: Modeling Energetic Particles, Cosmic Rays, and Magnetic Fields," *Space Science Reviews*, doi:10.1007/s11214-017-0354-8, 2017.

David Burgess

Professor of Mathematics and Astronomy
School of Physics and Astronomy, Queen Mary University of London
D.Burgess@qmul.ac.uk

Research Interests

Astrophysical and space plasma physics; theoretical and simulational plasma physics; computational physics; physics of collisionless plasma shocks and turbulence.

Research Activities

- Simulation of collisionless shocks and turbulence in space and astrophysical plasmas
- Particle acceleration in space and astrophysical plasmas.
- Theory of plasma waves, turbulence and instabilities
- Space plasma data analysis (Cluster, Ulysses)
- Co-Investigator Digital Wave Processor experiment, ESA mission Cluster. (NASA/GSFC Group Achievement Award: Cluster Science Team, 2004)
- ESA Ulysses and Cluster Guest Investigator
- Science Co-I on Solar Orbiter and Solar Probe Plus instruments
- PI STFC Consolidated Grant to Astronomy Unit, QMUL (2012-2016)
- Coordinator project SHOCK "Solar and Heliospheric Collisionless Kinetics: Enabling Data Analysis of the Sun to Earth Plasma System with Kinetic Modelling" (EU FP7 project), 2012-2015. Website: www.project-shock.eu

Education and Appointments

1980	B.A. Physics, Magdalen College, Oxford University
1984	PhD. Applied Mathematics, University of London, (Queen Mary College)
1984 – 1985	SERC Post-Doctoral Research Assistant, Queen Mary College, London
1985 – 1986	Royal Society European Science Exchange Fellowship, Observatoire de Paris-Meudon, France
1987 – 1988	Research Associate, Institute of Physical Science and Technology, University of Maryland, USA
1989 – 1994	SERC/PPARC Advanced Fellowship, Astronomy Unit, Queen Mary & Westfield College, London
1994 – 2008	Lecturer (to 1997) and Reader, Queen Mary & Westfield College, London
2008 – present	Professor of Mathematics and Astronomy, Astronomy Unit, Queen Mary University of London

Previous Recent ISSI Involvement

- 2011 Workshop on Particle Acceleration in Cosmic Plasmas
- 2012 Workshop on Microphysics of Cosmic Plasmas
- 2013 International Team: *Physics of the Injection of Particle Acceleration at Astrophysical, Heliospheric, and Laboratory Collisionless Shocks*
- 2016 International Team: *The Physics of the Very Local Interstellar Medium and its Interaction with the Heliosphere*

Selected Recent Publications (from over 100 publications in refereed journals)

[1] Gingell, I., S. J. Schwartz, D. Burgess et al. (16 additional authors), MMS Observations and Hybrid Simulations of Surface Ripples at a Marginally Quasi-Parallel Shock, *JGR*, 122, A11, 10.1002/2017JA024538, 2017.

[2] Sundberg, T., D. Burgess, M. Scholer, A. Masters, A. H. Sulaiman, The Dynamics of Very High Alfvén Mach Number Shocks in Space Plasmas, *ApJL*, 836, L4, 10.3847/2041-8213/836/1/L4, 2017.

[3] Sundberg, T., C.T. Haynes, D. Burgess, and C.X. Mazelle, Ion Acceleration at the Quasi-parallel Bow Shock: Decoding the Signature of Injection, *ApJ, 730,* 21, 10.3847/0004-637X/820/1/21, 2016.

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Education:

B.S.	Faculty of Science, University of Tokyo	1977-1981
M.S.	Faculty of Science, University of Tokyo	1981-1983
Ph.D.	Faculty of Science, University of Tokyo	1983-1986

Professional Career:

1986-1988: National Academy of Science and National Research Council/
NASA-GSFC, USA, Resident Research Associate
1988-1991: Lawrence Livermore National Laboratory/IGPP, USA
Post-Doctoral Research Associate
1991- 1993: Institute of Physical and Chemical Research (RIKEN), Japan
Special Researcher, Basic Science Program
1993-1999: Institute of Space and Astronautical Science (ISAS), Japan
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1999-present: The University of Tokyo,
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2012-present: The University of Tokyo, School of Science, Vice Dean
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Experience:
Research in space and astroplasma physics by means of theory, simulation and data analysis. Focused on the explosive energy release and particle acceleration in collisionless shocks and magnetic reconnection in various plasma environments, such as interplanetary shocks, supernova shocks, pulsar magnetosphere, and, the earth's magnetosphere. Author and co-author of 174 publications, 135 in peer-reviewed scientific journals and 30 refereed proceeding. Affiliated member of MMS science team.

Selected Publications:

1. M. Hoshino, Stochastic particle acceleration in multiple magnetic islands during reconnection, Phys. Rev. Lett., 108(13) doi:10.1103/PhysRevLett.108.135003 (2012)
2. M. Hoshino, Particle acceleration during magnetorotational instability in a collisionless accretion disk, Astrophy. J., DOI: 10.1088/0004-637X/773/2/118 (2013)
3. M. Hoshino, Angular momentum transport and particle acceleration during magnetorotational instability in a kinetic accretion disk, Physical Review Letters, DOI:10.1103/PhysRevLett.114.061101 (2015)
4. Y. Matsumoto, T. Amano, T. Kato, and M. Hoshino, Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave, Science, DOI:10.1126/science.1260168 (2015)
5. Y. Matsumoto, T. Amano, T. N. Kato, and M. Hoshino, Electron surfing and drift accelerations in a Weibel-dominated high Mach-number shock, Physical Review Letters, DOI:10.1103/PhysRevLett.119.105101 (2017)

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SUMMARY

Early career scientist with experience in spacecraft data analysis and numerical methods such as massively-parallel hybrid simulations. Research interests include kinetic plasma physics for shock microphysics, solar wind turbulence, reconnection, and ion-scale instabilities.

RESEARCH EXPERIENCE

April 2016 - present — **Research Associate, Imperial College London, Space and Atmospheres Group**
Investigation of ion- and electon-scale kinetic physics at Earth's bow shock, using a combination of data from NASA's Magnetospheric Multiscale mission and hybrid simulations.

July 2013 - April 2016 — **Research Associate, Queen Mary University of London, Astronomy Unit**
Numerical study of solar wind plasma turbulence, reconnection at ion-scale current sheets, shock microphysics and the ion-scale Kelvin-Helmholtz instability in Mercury's magnetosphere.

Apr 2013 - July 2013 — **Research Assistant, University of Warwick, Centre for Fusion, Space and Astrophysics**
Numerical study of the statistics of ion-scale structure formation at the outer regions of tokamaks.

Oct 2009 - Apr 2013 — **PhD research student, University of Warwick, Centre for Fusion, Space and Astrophysics**
3.5 year PhD research placement including development of hybrid particle-in-cell code for use in the simulation of ion-scale coherent structures, instabilities and collisionless shocks in fusion plasmas.

EDUCATION

2009 - 2013 — **University of Warwick**
PhD in Physics
Thesis: Hybrid simulations of flow bursts in magnetically confined plasmas

2005 - 2009 — **University of Cambridge, Downing College**
MSci + BA (Hons) in Astrophysics, 1st class

COLLABORATION
- Member of the FP7 SHOCK EU-funded project 2015-2016, which constituted collaboration on collisionless shock physics across 4 EU countries.
- Awarded 3.5 million core hours with the UK's DiRAC high performance computing facility as a co-investigator in a collaboration between Imperial and Queen Mary, 2015-2017.

TEACHING
- Academic tutor for 26 students at Imperial College (2017-present)
- Laboratory demonstrator for 2nd and 3rd year undergraduates (Imperial & Warwick)
- Closely supported the teaching of numerical methods for PhD students at Warwick and Queen Mary.

COMPUTING
- Experienced with use and development of massively-parallel, high-performance computing tools.
- Experienced with Matlab and IDL for data analysis.

COMMUNICATION
- Have given oral presentations at several large international conferences such as the AGU and EGU General Assemblies.
- Have presented at project workshops and conferences in the USA, UK, Austria, Italy and Belgium.

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