PROJECT: COORDINATED NUMERICAL MODELING OF THE GLOBAL JOVIAN AND SATURNIAN SYSTEMS

Team leaders / Coordinators: Dr. Licia RAY (University College London) and Dr. Japheth YATES (Imperial College London)

Abstract:

The past four decades have resulted in an abundance of in situ and remote observations of the jovian and saturnian magnetospheres, neutral atmospheres, and ionospheres (e.g. from Cassini, Galileo, Voyager, Pioneer, Ulysses, Hubble Space Telescope, Keck, SPRINT-A/Exceed). However, observations are limited in their spatial and temporal coverage. Effective data exploitation and interpretation depend on detailed numerical models to maximize the physical understanding gained from the extensive data sets available at Jupiter and Saturn. These models employ fundamental physics and known system parameters to simulate, and predict, the behavior of the jovian and saturnian systems. By increasing the communication between models of different physical regimes, we will significantly improve our ability to exploit and interpret data sets from Jupiter and Saturn, as well as help guide future mission planning.

We propose an international team, hosted by ISSI, to develop a comprehensive numerical description of the jovian and saturnian global systems from the outer magnetosphere, where the solar wind interacts with the magnetopause, to the upper planetary atmosphere. Currently, models focus on a specific spatial domain (i.e., magnetosphere, atmosphere, etc.), using simplified boundary conditions to approximate the neighboring regions. We plan to build a global view of the numerical system by: (1) comparing and contrasting the existing models within the same physical regime; (2) refining model boundaries and inputs to increase the exchange of information between models of two neighbouring spatial regimes; and (3) standardizing visualizations, data assimilation, and communication of model details and results to maximize usefulness to the broader community.

The proposed team is composed of experts from the following areas of numerical modeling: general circulation models of the neutral atmosphere, magnetosphere-ionosphere coupling, ionospheric electron transport and global magnetospheric magnetohydrodynamics. Some of our team members are also experts in data analysis, which is essential for optimizing the usefulness of numerical models to the broader community. The proposed work will be carried out over the course of two separate one-week meetings (autumn 2014 and summer/autumn 2015) and we anticipate a substantive number of publications ensuing from this proposed team.

Schedule:

We plan to hold two meetings:
- *Autumn 2014*
- *Summer / Autumn 2015*

Scientific rationale, goals, and timeliness of project

Jupiter and Saturn host the two largest planetary systems in the Solar System, with many similarities: both planets are rapid rotators, with rotation periods of ~9.9 h and 10.6 h, respectively; both have magnetospheres with large sub-solar magnetopause distances of 65 - 95 R_J (Jovian radii) [*Joy et al., 2002*] and 20 - 25 R_S (Saturnian radii) [*Achilleos et al., 2008*]; and their atmospheres are dominated by hydrogen and helium. Additionally, each planet is orbited by a geologically active moon, Io at Jupiter and Enceladus at Saturn, which leads to ~350 - 1500 kg s^{-1} and ~10s - 280 kg s^{-1} plasma added to the respective magnetospheres (see review by *Bagenal & Delamere* [*2011*]). Rotational energy ultimately drives the atmospheric and magnetospheric dynamics. These two regions are coupled via electric currents that flow outwards from the atmosphere along the planetary magnetic field, radially in the magnetosphere, and then back towards the atmosphere along the magnetic field, closing in the ionosphere, which is the ionized part of the upper atmosphere. The ionosphere is coupled to the thermosphere, the neutral portion of the upper atmosphere, through ion-neutral collisions that transfer momentum.

Our understanding of these planetary systems has greatly improved since the first in situ observations made in the 1970s by Pioneer 10 (Jupiter) and Pioneer 11 (Saturn). In the past 40 years, there have been many more flybys and two dedicated orbiters, Galileo at Jupiter and Cassini at Saturn, which have provided measurements of the thermal and energetic plasma environment, magnetic field structure, auroral and radio emissions, and energetic neutral populations with limited coverage in local time, radius, and latitude. Radio occultations along with observations of Saturn electron discharge events, have offered insight into the density and structure of the planetary ionospheres [*Kliore et al., 2009; Fischer et al., 2011*]. Earth-based auroral observations have complemented these planetary-based measurements, providing estimates of the temperature and wind speeds in the upper atmosphere [e.g., *Stallard et al., 2002, 2007*], the energy deposited in the atmosphere by auroral electrons [e.g., *Gustin et al., 2004*], and the dynamics driving the auroral emissions [e.g., *Grodent et al., 2008; Clarke et al., 2009; Nichols et al., 2010*].

Single spacecraft measurements and remote observations offer limited insight into the physical processes that drive the system. At Earth, multi-spacecraft missions e.g., Cluster, Themis, are able to triangulate regions of the magnetosphere to separate spatial and temporal effects. Unfortunately, sending multiple spacecraft to Jupiter or Saturn is cost-prohibitive and thus unlikely to occur in the near future.

As such, the outer planet community relies heavily on numerical modeling of the gas giant systems to provide a physical context for in situ and remote observations. Data is used to describe initial states and boundary conditions, while the model predictions are compared to in situ measurements and remote observations. Different models exist for different spatial regions in the gas giant systems i.e., the magnetosphere, ionosphere, and thermosphere. Given the ever-increasing importance of magnetosphere-ionosphere-thermosphere coupling as a scientific research area e.g., to explain Saturn's observed variable periodicities, the proposed ISSI team will compare different modeling approaches for each spatial region, and determine how they can best be integrated to make progress towards truly coupled simulations of these giant planet systems. Advancing existing models will greatly improve the outer planet community's ability to interpret existing data sets and assist in planning future missions.

Topic 1: Comparing and contrasting models

Goals: 1.1 - Understand how the various global MagnetoHydroDynamic (MHD) models differ from each other, and what common methodologies they employ.

1.2 - Determine how the small-scale physical processes (e.g. radial transport, boundary layer plasma - wave instabilities) modeled by hybrid and convection models affect the predictions made with global MHD models across similar magnetospheric regions.

1.3 – Improve Magnetosphere-Ionosphere (M-I) coupling models to include all the following effects: variable Pedersen conductance; transient solar wind conditions; distortions of the magnetic field owing to changes in magnetospheric plasma content and pressure; the rotational 'decoupling' between the ionosphere and magnetosphere allowed by substantial field-aligned potentials; and the subcorotation of the neutral atmosphere.

1.4 - Clarify the differences between electron transport models and assess how the varying predictions for the precipitating energy distribution into the ionosphere affect the ensuing thermospheric flows and ionospheric, electrical conductances.

There are a number of global three-dimensional MHD models of Jupiter and Saturn, which primarily investigate rotationally and solar wind-driven magnetospheric dynamics. MHD models can predict physical processes and sources of electromagnetic fields, such as Vasyliunas- and Dungey-type reconnections [*Jia et al., 2012b*], Kelvin-Helmholtz waves [*Fukazawa et al., 2012*], and electrical current systems [*e.g., Walker and Ogino, 2003*]. Additionally, these robust models can reproduce fundamental magnetospheric properties, such as the quasi-periodic magnetic oscillations at Saturn [*Jia et al., 2012b*], and, at Jupiter, the magnetospheric plasma angular velocities, dawn-dusk asymmetry in the current sheet reported by *Khurana & Schwarzl [2005]* and the prenoon auroral oval discontinuity observed by *Radioti et al. [2008]* [*Chané & Saur, 2012*]. Individual MHD models vary with respect to location of the inner boundary and the grid resolution (see Topic 2).

Hybrid models combine kinetic theory and MHD, generally treating ions kinetically and electrons as a massless MHD fluid. The kinetic treatment of ions is particularly useful in boundary layers where the spatial scales of interest are on the order of, or less than, the ion gyroradius. As such, hybrid codes have been used to model viscous processes, such as Kelvin-Helmholtz Instabilities [*e.g. Delamere et al., 2011*] and plasma interactions in multi-plasma environments [*e.g. Kriegel et al., 2009*].

Convection models frequently focus on centrifugally-driven processes. The rapid rotation of the giant planets results in strong centrifugal forces that drive relatively cold, dense magnetospheric plasma radially outwards through the magnetosphere. The Rice Convection Model [*Pontius et al., 1998; Liu et al., 2010*] has been applied to Jupiter and more recently to Saturn, predicting centrifugally-driven fingers of hot, tenuous plasma that protrude into the inner magnetosphere while, at the same time, cold, dense plasma is transported outwards. In M-I coupling models, the magnetosphere is coupled to the ionosphere, and hence thermosphere, by simulated auroral currents that flow along the magnetic field lines. These currents thus transfer angular momentum and energy between the atmosphere and magnetosphere. They are influenced by the ratio of the Pedersen conductance to plasma mass outflow rate [*Nichols et al. 2004*]; changes in magnetospheric configuration, either by the solar wind [*Yates et al. 2014*] or plasma pressure in the magnetosphere [*Achilleos et al. 2010, Nichols 2011*]; the presence of field-aligned potentials at high magnetic latitudes [*Nichols et al. 2005; Ray et al. 2010,2012,2014*]; and the subcorotation of the neutral thermosphere relative to the deep planet [*Smith & Aylward, 2008,2009; Müller-Wodarg, 2006,2012; Tao et al., 2009*]. However, no model has yet included all of these effects self-consistently.

Completing the suite are electron transport and atmospheric models. Electron transport models fall into three broad categories: numerically solving the Boltzmann equation [*e.g., Grodent et al., 2001; Galand et al., 2011*], the Continuous Slowing Down Approximation [*Rego et al., 1994*], or a Monte Carlo approach [*Hiraki and Tao, 2008; Tao et al., 2011*]. All methods trace incoming electron streams of a specified energy distribution, which then interact with a prescribed neutral atmosphere, yielding ionization of the neutrals and heating of the thermal electrons; however, the predicted ionization rates differ depending on the method used. Ionospheric models utilize the ionization and thermal electron heating rates prescribed by the electron transport codes to determine the temperature and density of the planetary ionospheres. Working in conjunction with neutral thermosphere models [*e.g. Müller-Wodarg et al., 2006,2012; Smith & Achilleos, 2012*], the complete atmospheric suite of models can predict thermospheric and ionospheric winds, temperatures and densities, as well as ionospheric electrical conductances [*Millward et al., 2002; Moore et al., 2010; Galand et al. 2011*].

Topic 2: Refining the boundaries

Goals: 2.1 - Determine the inputs and boundary conditions required for each model, and the numerical limitations that constrain the choice of boundary.

2.2 - Optimize or parameterize model output for use as input into a neighboring module.

2.3 - Quantify how adjustments to boundary conditions and input will improve the physical and numerical description of the global system.

Each model requires boundary conditions and/or initial state parameters, depending on the physical region described. Stepping inwards from the magnetopause boundary towards the planetary atmosphere, these boundary conditions and initial parameters are: the velocity, density, pressure, and temperature of the solar wind, and the interplanetary magnetic field strength and orientation, at the magnetopause; planetary magnetic field structure; magnetospheric plasma density, composition and radial mass transport rate; auroral electrons spectra, morphology, and variability; auroral and solar energy deposited in the planetary atmosphere; ionospheric Pedersen conductance and electric field; and finally, the atmospheric density profile as a function of altitude.

Many of these boundary conditions can be extrapolated from in situ data and remote observations. However, limited spatial and temporal coverage requires alternate seed conditions for some of the numerical models. One of the main goals of this international team is to determine which boundary conditions can be integrated in the most seamless manner from one type of model to a neighboring module. This will improve the coupling between the thermosphere, ionosphere, and magnetosphere and allow local physical properties, which are otherwise too computationally intensive to evaluate, to affect neighboring regions as part of a more realistic simulated system that can be then compared to existing data sets.

The first step in creating more ‘transparent’ model edges is to define how the boundary conditions are implemented in each model. For example, MHD models apply either a constant ionospheric Pedersen conductance [*Kidder et al., 2009; Jia et al., 2012a*] or a fixed ion-neutral collision frequency [*Chané & Saur, 2012*] at the atmospheric boundary, which is approximated as a sphere with a radius ranging from 2 to 6 planetary radii, in order to resolve the Alfvén speed. Meanwhile, M-I coupling models may implement a variable Pedersen conductance at the planetary ionosphere that is modified under the action of electron precipitation [*Nichols & Cowley, 2004; Ray et al., 2010; Yates et al., 2012*]. However, both the MHD and M-I coupling model treatments, by necessity, simplify the interaction between the ionosphere and thermosphere.

The ionospheric Pedersen conductance is itself an output of the atmospheric models. Ionospheric densities are determined as a result of auroral energy deposition using an electron transport code [*e.g. Galand et al., 2011*] coupled to a model of the ionosphere [*e.g. Moore et al., 2010*]. Thermospheric densities and temperatures [*e.g. Müller-Wodarg et al., 2006*] are required as input for both types of model. Therefore, a fully self-consistent calculation should account for the influence of the ionosphere and thermosphere.

After increasing the communication between neighbouring numerical models, we aim to quantify how the modified inputs affect the numerical predictions. For example, does including a variable Pedersen conductance in an MHD model change the predicted timing of plasmoid release down Saturn's magnetotail? Through comparisons with data, we will improve our understanding of the underlying physics in the jovian and saturnian systems, and, by comparing numerical models amongst themselves we will be able to separate numerical artifacts from physical insights.

Topic 3: Visualization, data assimilation, and communication
Goals: 3.1 - Are there more effective ways to compare numerical output to available data (e.g., statistical or data assimilation-based techniques) to maximize the insight that models provide for data interpretation?
3.2 - How can numerical modelers better communicate the strengths, assumptions and limitations intrinsic to the models such that we increase their usefulness to the broader community?

Finally, the proposed ISSI team aims at improving upon, and sharing, techniques to communicate the outputs, strengths, assumptions, and limitations of numerical models to the broader community. Modelers and observers often work independently of each other; however, numerical models provide insight into the physics behind the data, along with aiding in future mission planning. Increasing the cohesion of the outer planet community in this regard is essential to maximizing how models aid data interpretation and exploitation.

One method, used in 3D MHD and hybrid simulations, is to directly compare spacecraft data to numerical simulations by 'flying' a virtual spacecraft through the simulation domain [e.g. *Delamere et al., 2011; Jia et al., 2012a*], producing virtual 'measurements' as a function of location and time. Unfortunately, this technique is less effective for atmospheric models as no in situ data are available and remote-sensing and radio occultation data are reduced to vertical profiles of the electron density at dawn and dusk. However, auroral emission rates in the IR can be used to derive the density and temperature of H_3^+, which may then be compared with atmospheric models [*Tao et al., 2011*]. Likewise, the characteristics of auroral electrons derived from spectroscopic analysis of the aurorae are directly compared to auroral current models. Further improvement to visualizations of model outputs and data-model comparisons will increase the usefulness and accessibility of numerical models to the broader community.

Timeliness of the project

The proposal of this ISSI team comes at a crucial time in giant planets system science. Cassini is currently in orbit around Saturn, and, in the coming years, will re-enter the high-latitude regions of Saturn, precisely where the boundaries between our models exist. The JAXA satellite Sprint-A/Hisaki/EXCEED, launched in September 2013, is currently observing the planets and their local environments simultaneously, e.g. the Io plasma torus and Jupiter's aurora, in EUV wavelengths. Likewise, the Juno spacecraft will arrive at Jupiter in 2016, entering into a polar orbit that will pass through the high-latitude auroral regions. Instrument development and observation planning for ESA's

JUICE mission, which rely on numerical predictions of the radiation environment and magnetospheric conditions, are occurring now and over the next decade.

Hence, now is the time to develop numerical tools for the current, as well as next, generation of missions. The present availability of outer planets data is unprecedented and will only increase over the next two decades. Improving the existing numerical models, and the community's ability to interpret existing in situ measurements and remote observations, will increase our understanding of the underlying physics. As the giant planet systems are analogues to stellar systems, advances in numerical models will also have implications for exoplanets and stellar system formation.

List of the expected output

The results of the Numerical Modeling team will have a long-lasting impact on the outer planet community. The main scientific output will be a more integrative approach to the boundaries of, and the interfacing between, magnetospheric and atmospheric models, in which the output from one type of model can be used directly as input for the neighboring spatial region. Additionally, team members will gain a more comprehensive understanding of the various types of numerical models, along with a better knowledge of how to communicate the insight gained from numerical models to the broader community. These advances will significantly impact the interpretation and exploitation of existing data sets, as well as assisting mission planning and the development of future instrumentation. We expect that the collaborations resulting from the team study will lead to at least 3 scientific peer reviewed publications.

Added value provided by ISSI

ISSI provides the ideal environment to gather scientists from the US and European communities to directly compare and discuss the numerical models currently used in the outer planets community. The intimate nature of the International Team is perfect for delving into complex details, while also providing a forum for 'big picture' discussions. Additionally, the access to internet facilities, and therefore ability to adjust and run participant models in real time, is an important step in, eventually, merging and cross-validating the models.

List of confirmed members [for contact information see *Annex B,* and for short CVs see *Annex c*]:

Nick Achilleos, Emmanuel Chané, Peter Delamere, Marina Galand, Xian Zhe Jia, Luke Moore, Jonathan Nichols, Licia Ray, Joachim Saur, Chihiro Tao, Robert Winglee, Japheth Yates

Schedule of the project

We plan to hold two meetings, each 5 days long, with the first meeting occurring in the autumn of 2014 and the second to be held approximately a year later in autumn of 2015. The first meeting will focus on understanding the differences between similar models and refining the boundary conditions between models. Between the first and second meetings, team members will adapt and test their numerical models using the knowledge gained during the first meeting. Results from improved models of similar type will be compared in the second meeting and further efforts will be made towards refining the boundaries between models in adjacent spatial regions, leading to a more global numerical description of the jovian and saturnian systems. Visualization and communication techniques will feature at both meetings.

Financial support requested from ISSI and facilities required

We request from ISSI financial support for 12 members x 5 days x 2 meetings = 120 per diems, plus the travel costs of the team leader and support for a young scientist to be named later. While at ISSI, we plan to use many of the facilities available: meeting room with white boards, wireless internet, and Skype video-conferencing, should a member of the team not be able to attend.

ANNEX A: REFERENCES

Achilleos, N., C. S. Arridge, C. Bertucci, C. M. Jackman, M. K. Dougherty, K. K. Khurana, and C. T. Russell (2008), Large-scale dynamics of Saturn's magnetopause: Observations by Cassini, *J. Geophys. Res., 113*, A11209, doi:10.1029/2008JA013265.

Achilleos, N., P. Guio, C. S. Arridge, N. Sergis, R. J. Wilson, M. F. Thomsen, and A. J. Coates (2010), Influence of hot plasma pressure on the global structure of Saturn's magnetodisk, *Geophys. Res. Lett., 37*, L20201, doi:10.1029/2010GL045159.

Bagenal, F. and P. A. Delamere (2011), Flow of mass and energy in the magnetospheres of Jupiter and Saturn, *J. Geophys. Res.*, *116*, A05209, doi:10.1029/2010JA016294.

Chané, E. and J. Saur (2012), Global Simulations of the Jovian Magnetosphere, *Fall American Geophysical Meeting,* San Francisco, CA.

Clarke, J. T., J. Nichols, J.-C. Gérard, D. Grodent, K. C. Hansen, W. Kurth, G. R. Gladstone, J. Duval, S. Wannawichian, E. Bunce, S. W. H. Cowley, F. Crary, M. Dougherty, L. Lamy, D. Mitchell, W. Pryor, K. Retherford, T. Stallard, B. Zieger, P. Zarka, and B. Cecconi (2009), Response of Jupiter's and Saturn's auroral activity to the solar wind, *J. Geophys. Res.*, 114, A05210, doi:10.1029/2008JA013694.

Delamere, P. A., R. J. Wilson, and A. Masters (2011), Kelvin-Helmholtz instability at Saturn's magnetopause: Hybrid simulations, *J. Geophys. Res., 116*, A10222, doi:10.1029/2011JA016724.

Fischer, G., D. A. Gurnett, P. Zarka, L. Moore, and U. A. Dyudina (2011), Peak electron densities in Saturn's ionosphere derived from the low-frequency cutoff of Saturn lightning, *J. Geophys. Res., 116*, A04315, doi:10.1029/2010JA016187.

Fukazawa, K., T. Ogino, and R. J. Walker (2012), A magnetohydrodynamic simulation study of Kronian field-aligned currents and auroras*, J. Geophys. Res., 117*, A02214, doi:10.1029/2011JA016945.

Galand, M., L. Moore, I. Mueller-Wodarg, M. Mendillo, and S. Miller (2011), Response of Saturn's auroral ionosphere to electron precipitation: Electron density, electron temperature, and electrical conductivity, *J. Geophys. Res., 116,* A09306, doi:10.1029/2010JA016412.

Grodent, D., J. H. Waite Jr., and J.-C. Gérard (2001), A self-consistent model of the Jovian auroral thermal structure, *J. Geophys. Res., 106(A7)*, 12933–12952, doi:10.1029/2000JA900129.

Grodent, D., J.-C. Gérard, A. Radioti, B. Bonfond, and A. Saglam (2008a), Jupiter's changing auroral location, *J. Geophys. Res.*, 113, A01206, doi:10.1029/2007JA012601.

Gustin, J., J.-C. Gérard, D. Grodent, S. W. H. Cowley, J. T. Clarke, and A. Grard (2004), Energy-flux relationship in the FUV Jovian aurora deduced from HST-STIS spectral observations, *J. Geophys. Res., 109*, A10205, doi:10.1029/2003JA010365.

Hiraki, Y. and C. Tao (2008), Parameterization of ionization rate by auroral electron precipitation in Jupiter, *Ann. Geophys., 26*, 77-86, doi:10.5194/angeo-26-77-2008.

Jia, X., M. G. Kivelson, and T. I. Gombosi (2012a), Driving Saturn's magnetospheric periodicities from the upper atmosphere/ionosphere, *J. Geophys. Res., 117*, A04215, doi:10.1029/2011JA017367.

Jia, X., K. C. Hansen, T. I. Gombosi, M. G. Kivelson, G. Tóth, D. L. DeZeeuw, and A. J. Ridley (2012b), Magnetospheric configuration and dynamics of Saturn's magnetosphere: A global MHD simulation, *J. Geophys. Res., 117*, A05225, doi:10.1029/2012JA017575.

Joy, S. P., M. G. Kivelson, R. J. Walker, K. K. Khurana, C. T. Russell, and T. Ogino (2002), Probabilistic models of the Jovian magnetopause and bow shock locations, *J. Geophys. Res., 107,* 1309, doi: 10.1029/2001JA009146.

Khurana, K. K. and H. K. Schwarzl (2005), Global structure of Jupiter's magnetospheric current sheet, *J. Geophys. Res.*, *110*, doi:10.1029/2004JA010757.

Kidder, A., R. M. Winglee, and E. M. Harnett (2009), Regulation of the centrifugal interchange cycle in Saturn's inner magnetosphere, *J. Geophys. Res., 114,* A02205, doi:10.1029/2008JA013100.

Kliore, A. J., A. F. Nagy, E. A. Marouf, A. Anabtawi, E. Barbinis, D. U. Fleischman, and D. S. Kahan (2009), Midlatitude and high-latitude electron density profiles in the ionosphere of Saturn obtained by Cassini radio occultation observations, *J. Geophys. Res., 114,* A04315, doi:10.1029/2008JA013900.

Kriegel, H., S.Simon, J. Müller, U. Motschmann, J. Saur, K.-H. Glassmeier, and M. K. Dougherty (2009) The plasma interaction of Enceladus: 3D hybrid simulations and comparison with Cassini MAG data, *Planetary and Space Science, 57,* doi:10.1016/j.pss.2009.09.025.

Liu, X., T. W. Hill, R. A. Wolf, S. Sazykin, R. W. Spiro, and H. Wu (2010), Numerical simulation of plasma transport in Saturn's inner magnetosphere using the Rice Convection Model, *J. Geophys. Res., 115*, A12254, doi:10.1029/2010JA015859.

Millward, G., S. Miller, T. Stallard, and A. D. Aylward (2002), On the Dynamics of the Jovian Ionosphere and Thermosphere III. The Modelling of Auroral Conductivity, *Icarus, 160,* 95-107, doi:10.1006/icar.2002.6951.

Moore, L., I. Mueller-Wodarg, M. Galand, A. Kliore, and M. Mendillo (2010), Latitudinal variations in Saturn's ionosphere: Cassini measurements and model comparisons*, J. Geophys. Res., 115*, A11317, doi:10.1029/2010JA015692.

Müller-Wodarg, I. C. F., M. Mendillo, R. V. Yelle, and A. D. Aylward (2006), A global circulation model of Saturn's thermosphere, *Icarus, 180,* 147-160, doi:10.1016/j.icarus.2005.09.002.

Müller-Wodarg, I. C. F., L. Moore, M. Galand, S. Miller, and M. Mendillo (2012), Magnetosphere-atmosphere coupling at Saturn: 1 – Response of thermosphere and ionosphere to stead state polar forcing, *Icarus, 221,* 481-494, doi:10.1016/j.icarus.2012.08.034.

Nichols, J. D. and S. W. H. Cowley (2004), Magnetosphere-ionosphere coupling currents in Jupiter's middle magnetosphere: effect of precipitation-induced enhancement of the ionospheric Pedersen conductivity, *Ann. Geophys., 22,* 1799-1827, doi:10.5194/angeo-22-1799-2004.

Nichols, J. D. and S. W. H. Cowley (2005), Magnetosphere-ionosphere coupling currents in Jupiter's middle magnetosphere: effect of magnetosphere-ionosphere decoupling by field-aligned auroral voltages, *Ann. Geophys., 23*, 799-808, doi:10.5194/angeo-23-799-2005.

Nichols, J. D., S. W. H. Cowley, and L. Lamy (2010), Dawn-dusk oscillation of Saturn's conjugate auroral ovals, *Geophys. Res. Lett., 37*, L24102, doi:10.1029/2010GL045818.

Nichols, J. D. (2011), Magnetosphere-ionosphere coupling in Jupiter's middle magnetosphere: Computations including a self-consistent current sheet magnetic field model, *J. Geophys. Res., 116*, A10232, doi:10.1029/2011JA016922.

Pontius Jr., D. H., R. A. Wolf, T. W. Hill, R. W. Spiro, Y. S. Yang, and W. H. Smyth (1998), Velocity shear impoundment of the Io plasma torus, *J. Geophys. Res., 103(E9)*, 19935–19946, doi:10.1029/98JE00538.

Radioti, A., J.-C. Gérard, D. Grodent, B. Bonfond, N. Krupp, and J. Woch (2008a), Discontinuity in Jupiter's main auroral oval, *J. Geophys. Res.*, *113*, A01215, doi:10.1029/2007JA012610.

Ray, L. C., R. E. Ergun, P. A. Delamere, and F. Bagenal (2010), Magnetosphere-ionosphere coupling at Jupiter: Effect of field-aligned potentials on angular momentum transport, *J. Geophys. Res., 115*, A09211, doi:10.1029/2010JA015423.

Ray, L. C. , N. A. Achilleos, J. N. Yates (submitted), Including field-aligned potentials in the coupling between Jupiter's thermosphere, ionosphere, and magnetosphere, *Planetary and Space Science.*

Ray, L. C., R. E. Ergun, P. A. Delamere, and F. Bagenal (2012), Magnetosphere-ionosphere coupling at Jupiter: A parameter space study, *J. Geophys. Res., 117*, A01205, doi:10.1029/2011JA016899.

Rego, D., R. Prangé, and J.-C. Gérard (1994), Auroral Lyman α and H_2 bands from the giant planets: 1. Excitation by proton precipitation in the Jovian atmosphere, *J. Geophys. Res., 99(E8)*, 17075–17094, doi:10.1029/93JE03432.

Stallard, T., S. Miller, G. Millward, and R. D. Joseph (2002), On the Dynamics of the Jovian Ionosphere and Thermosphere II. The Measurement of H_3^+ Vibrational Temperature, Column Density, and Total Emission, *Icarus, 156,* 498-514, doi:10.1006/icar.2001.6793.

Stallard, T., S. Miller, H. Melin, M. Lystrup, M. Dougherty, and N. Achilleos (2007), Saturn's auroral/polar H_3^+ infrared emission I. General morphology and ion velocity structure, *Icarus, 189,* 1-13, doi:10.1016/j.icarus.2006.12.027.

Smith, C. G. A. and A. D. Aylward (2008), Coupled rotational dynamics of Saturn's thermosphere and magnetosphere: a thermospheric modelling study, *Ann. Geophys., 26*, 1007-1027, doi:10.5194/angeo-26-1007-2008.

Smith, C. G. A. and A. D. Aylward (2009), Coupled rotational dynamics of Jupiter's thermosphere and magnetosphere, *Ann. Geophys., 27,* 199-230, doi:10.5194/angeo-27-199-2009.

Smith, C. G. A. and N. Achilleos (2012), Axial symmetry breaking of Saturn's thermosphere, *Monthly Notices of the Royal Astronomical Society, 422,* 1460-1488, doi:10.1111/j.1365-2966.2012.20719.x.

Tao, C., H. Fujiwara, and Y. Kasaba (2009), Neutral wind control of the Jovian magnetosphere-ionosphere current system, *J. Geophys. Res., 114*, A08307, doi:10.1029/2008JA013966.

Tao, C., S. V. Badman, and M. Fujimoto (2011), UV and IR auroral emission model for the outer planets: Jupiter and Saturn comparison, *Icarus, 213,* 581-592, doi:10.1016/j.icarus.2011.04.001.

Walker, R. J. and T. Ogino (2003), A simulation study of currents in the Jovian magnetosphere, *Planetary and Space Sciences, 51,* 295-307, doi:10.1016/S0032-0633(03)00018-7.

Yates, J. N., N. Achilleos, P. Guio (2012), Influence of upstream solar wind on thermospheric flows at Jupiter, *Planetary and Space Science, 61,* 15-31, doi:10.1016/j.pss2011.08.007.

Yates, J. N., N. Achilleos, and P. Guio (2014), Response of the Jovian thermosphere to a transient 'pulse' in solar wind pressure, *Planetary and Space Science,* http://*dx.*doi.org/10.1016/j.pss.2013.11.009

ANNEX B: Contact Information for Confirmed Participants

Nicholas ACHILLEOS	University College London Dept. of Physics & Astro. Gower Place London WC1E 6BT, **UK**	T: +44 (0)20 7679 2671 F: +44 (0)20 7679 7153	Nicholas.achilleos@ucl.ac.uk
Emmanuel CHANÉ	Centre for Mathematical Plasma-Astrophysics Katholieke Universiteit Leuven Celestijnenlaan 200B B-3001 Leuven **BELGIUM**	T: +32 163 723 80	emmanual.chane@wis.kuleuven.be
Peter DELAMERE	Geophysical Institute University of Alaska Fairbanks Fairbanks, AK 9975-7320 **USA**	T: +1 (907) 474 6442 F: +1 (907) 474-7290	Peter.Delamere@gi.alaska.edu
Marina GALAND	Space & Atmospheric Physics Group Dept. of Physics Imperial College Prince Consort Road London, SW7 2AZ, **UK**	T: +44 (0)20 7594 1771 F: +44 (0)20 7594 7900	m.galand@imperial.ac.uk
Xianzhe JIA	Dept. of Atmospheric, Oceanic & Space Sciences Space Research Building 2455 Hayward St. Ann Arbor, MI 48109-2143 **USA**	T: +1 (734) 764 7220 F: +1 (734) 647 3083	xzjia@umich.edu
Luke MOORE	Boston University Center for Space Physics 725 Commonwealth Ave. Boston, MA 02215 **USA**	T: +1 (617) 353 7410 F: +1 (617) 353 6463	moore@bu.edu
Jonathan NICHOLS	Dept. of Physics & Astronomy University of Leicester University Road Leiceseter, LE1 7RH, **UK**	T: +44 (0)116 252 5049 F: +44 (0)116 252 3555	jdn@ion.le.ac.uk
Licia RAY	University College London Dept. of Physics & Astro. Gower Place London WC1E 6BT,**UK**	T: +44 (0)20 7679 2446 F: +44 (0)20 7679 7153	Licia.ray@ucl.ac.uk
Joachim SAUR	Institute of Geophys. & Meteorology University of Cologne Albertus-Magnus-Platz D-50923 Cologne, **GERMANY**	T: +49-221-470-2310 F: +49-221-470-5198	saur@geo.uni-koeln.de
Chihiro TAO	Institut de Recherche en Astrophysique et Planétologie (IRAP) 9 Avenue du Colonel Roche, 31028 Toulouse, **FRANCE**	T: +33 (0)561 55 66 81	chihiro.tao@irap.omp.eu
Robert WINGLEE	Dept. of Earth & Space Sciences University of Washington Seattle, WA 98185-1310 **USA**	T: +1 (206) 685 8160	winglee@ess.washington.edu
Japheth YATES	Space & Atmospheric Physics Group Dept. of Physics Imperial College Prince Consort Road London, SW7 2AZ, **UK**	T: +44 (0)20 7594 1155 F: +44 (0)20 7594 7900	japheth.yates@imperial.ac.uk

** EU Participants are highlighted*

ANNEX C: One page CVs for confirmed participants in alphabetical order by last name

Name	Dr. Nicholas Achilleos
Address	Department of Physics and Astronomy University College London Gower Place LONDON, United Kingdom, WC1E 6BT
Email	nicholas.achilleos@ucl.ac.uk
Position	Lecturer in Physics
Brief CV	**Education**: BSc (Hons I), Physics, Univ. of Queensland (Australia), 1985 PhD, Astronomy and Astrophysics, Australian National University, 1992 Distinctions from Open University in 'Group Theory' and 'Network Design', 2002-4 **Professional Background**: • 8/9-2012 Visiting Professor, Japanese Aerospace Exploration Agency • 01-2010 Chair of UK 'Miracle' Consortium for High-Performance Computing in Astrophysics • 04-2007 Lecturer in Physics, University College London • 05-2002 Cassini Magnetometer Support Scientist and Operations Engineer, Imperial College London • 01-2000 Software Engineer and Team Leader, Logica plc, UK • 01-1994 Postdoctoral Research Associate, University College London • 11-1991 Attaché de Recherche, University of Montreal **Awards:** 2009 - NASA Group Achievement Awards: 'Cassini Magnetosphere and Titan Target Working Teams' 2008 - New Journal of Physics 10th Anniversary Research Highlight 2006 - Imperial College Bonus Award for services on Cassini project **Recent spacecraft mission involvement:** • Science co-I for JUICE Magnetometer • Cassini Magnetometer Support Scientist / Operations Engineer **Publications:** 82 publications **Selected relevant publications:** Smith, C. G. A. and Achilleos, N., Axial symmetry breaking of Saturn's thermosphere, *M.N.R.A.S.*, **422**, 1460-1488, 2012. Achilleos, N. et al., Influence of hot plasma pressure on the global structure of Saturn's magnetodisk, *Geophys. Res. Lett.*, **37**, L20201, 2010. Achilleos, N. et al., A model of force balance in Saturn's magnetodisc, *M.N.R.A.S.*, **401**, 2349-2371, 2010. Achilleos, N. et al., Large-scale dynamics of Saturn's magnetopause: Observations by Cassini, *J. Geophys. Res.*, **113**, A11209, 2008.

EMMANUEL CHANÉ

CURRICULUM VITAE

2014/03/14

Centre for mathematical Plasma-Astrophysics
Katholieke Universiteit Leuven
Celestijnenlaan 200B
B-3001 Leuven
e-mail: emmanuel.chane@wis.kuleuven.be
phone: +32-163-723-80

Private Address:
Middelweg 45
B-3001 Leuven
phone: +32-486-682-806

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)

2002 Maîtrise of Physics, University of Lille (France)

EMPLOYMENT:

2013-2014 Postdoctoral Researcher, Centre for mathematical Plasma-Astrophysics, Katholieke Universiteit Leuven (Belgium). Since September 2013

2013 Research Scientist, Space Science Center, University of New Hampshire (USA). 2013 May – July

2010-2013 Postdoctoral Researcher, Institute of Geophysics and Meteorology, University of Cologne (Germany)
Visiting Scientist at the University of New Hampshire since August 2012

2009-2010 Postdoctoral Researcher, Centre for mathematical Plasma-Astrophysics, Katholieke Universiteit Leuven (Belgium)
Visiting Scientist at the University of Cologne

Dr. Peter A. Delamere: Curriculum Vitae

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 inner 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, studying magnetospheric dynamics at Jupiter and Saturn and solar wind interactions with comets and Pluto.

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

May 1998 - Dec 1999: Post Doctoral Fellow at Geophysical Institute, University of Alaska Fairbanks, studying energy and momentum coupling between injected plasma and ambient plasma populations. Participated in the Calcium rocket campaign and Active Plasma Experiment (APEX) conducted at Poker Flat Research Range, Fairbanks, Alaska.

Professional Organizations

Member, American Geophysical Union since 1992.

Selected Publications and Work in Progress

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 vortices 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.

Delamere, P. A., R. J. Wilson, and F. Bagenal, Kelvin-Helmholtz instability at Saturn's magnetopause: Hybrid simulations, *Journal of Geophysical Research*, *116*, A10,222, 2011.

Delamere, P. A., and F. Bagenal, Solar wind interaction with Jupiter's magnetosphere, *Journal of Geophysical Research (Space Physics)*, *115*, 10,201–+, 2010.

Marina GALAND

Space and Atmospheric Physics Group
Department of Physics - Imperial College
Prince Consort Road
London, SW7 2AZ – U.K.

Phone: +44 (0)20 7594 1771
Fax: +44 (0)20 7594 7900
E-mail: m.galand@imperial.ac.uk
http://www3.imperial.ac.uk/people/m.galand

RESEARCH INTERESTS:

My principal research interest is the **study of planetary atmospheres**. In particular, I investigate solar and auroral particle energy deposition and redistribution in atmospheres of bodies throughout the solar system, using sophisticated state-of-the-art kinetic and fluid models which I have developed for the past 20 years. Through close collaborations with science teams of major space missions (e.g., Cassini) I have used my models as organizing elements between datasets from different instruments and thus optimized the scientific output from such measurements. I closely **collaborate** with colleagues within Europe, USA and Asia. I am a **Co-Investigator** of the UV Imaging Spectrograph (UVS) and the Radio and Plasma Wave Investigation (RPWI), ESA/JUpiter ICy Moon Explorer (JUICE). I have **published** more than 45 scientific papers in major refereed journals. I am regularly invited to give **presentations at conferences and summer schools** (6 since 2013). My work has been rewarded by the Zeldovich Medal.

ACADEMIC DEGREES

Ph.D.: University of Grenoble, France, 1996.
Master in physics: University of Strasbourg, France, 1993.
Degree in engineering: ENSPS (*Ecole Nationale Supérieure de Physique de Strasbourg*), 5-year program, University of Strasbourg, France, 1993.

WORK EXPERIENCE after PhD

Oct. 2010 – present:	**Senior Lecturer in Planetary Physics**, Space and Atmospheric Physics Group, Department of Physics, Imperial College London, U.K.
Apr. 2011 – present:	**Visiting Researcher**, Center for Space Physics, Boston University, MA, USA
Aug. 2005 – Sept. 2010:	**Lecturer in Planetary Physics**, Space and Atmospheric Physics Group, Department of Physics, Imperial College London, U.K.
Jan. 2002 – July 2005:	**Senior Research Associate,** Center for Space Physics, BU, MA, USA.
June 2000 – Dec. 2001:	**Research Associate**, Center for Space Physics, BU, MA, USA.
Nov. 1998 – May 2000:	**Research Associate:** *National Research Council* Research Associateship, Space Environment Center, NOAA, Boulder, Colorado, USA.
Nov. 1996 - Oct. 1998:	**Post-doc:** *Advanced Study Program* postdoctoral fellowship, High Altitude Observatory, NCAR, Boulder, Colorado, USA.

SELECTION OF RECENT PUBLICATIONS:

Galand M., L. Moore, B. Charnay, I. Müller-Wodarg, and M. Mendillo (2009), Solar primary and secondary ionization at Saturn, *J. Geophys. Res.*, *114*, A06313, doi:10.1029/2008JA013981.

Galand, M., L. Moore, I. Müller-Wodarg, M. Mendillo, and S. Miller (2011), Response of Saturn's auroral ionosphere to electron precipitation: electron density, electron temperature, and electrical conductivity, *J. Geophys. Res.*, *116*, A09306, doi:10.1029/2010JA016412.

Ray, L. C., **M. Galand**, L. E. Moore, and B. Fleshman (2012), Characterizing the limitations to the coupling between Saturn's ionosphere and middle magnetosphere, *J. Geophys. Res., 117*, A07210, doi:10.1029/2012JA017735.

Ray, L.C., **M. Galand**, P. Delamere, and B. Fleshman (2013), Current-voltage relation for the saturnian system, *J. Geophys. Res.*, *118*, doi:10.1002/jgra.50330.

Name: Dr. Xianzhe Jia

Education:
2003 – 2009: M.S. & Ph.D., University of California at Los Angeles, Los Angeles, USA
1995 – 2002: B.S. & M.S., University of Science and Technology of China, Hefei, China

Current Position: Assistant Research Scientist / University of Michigan

Contact Details: Department of Atmospheric, Oceanic and Space Sciences, University of Michigan
Space Research Building, 2455 Hayward St.
Ann Arbor, MI 48109-2143, USA
Tel: + 001-734-764-7220; Fax: + 001-734-647-3083; Email: xzjia@umich.edu

Scientific Interests:
- Global MHD simulations of planetary magnetospheres and plasma-moon interactions
- Large-scale dynamics and plasma transport of planetary magnetospheres
- Magnetic properties of the satellites of Jupiter and Saturn

Synergistic Activities:
- Reviewer for journals*: JGR-Space Physics; JGR-Planets; Geophysical Research Letters; Reviews of Geophysics; Nature Geoscience; Planetary and Space Science; Icarus*
- Panel reviewer: NASA Outer Planets Research Program; NASA Planetary Mission Data Analysis Program
- Mail-in reviewer: NASA Postdoctoral Program; NASA LASER; NSF ATM/GEO Program
- Member of the science program committee of the 2013 AGU Chapman conference on "Fundamental properties and processes of magnetotails", Reykjavik, Iceland
- Member of the Scientific Organization Committee of the 2011 Solar/Space MHD International Summer School, Hefei, China
- Invited participant of the *ISSI* workshops on "Plasma sources in solar system magnetospheres" [2013], "Giant Planet Magnetodiscs and Aurorae" [2012], and "Planetary Magnetism" [2008]
- Team member of the *ISSI* international teams of "*Modes of plasma radial motion in planetary systems*" [2013-2014] and "*Investigating the Dynamics of Planetary Magnetotails*" [2010-2011]

Space Missions:
- Co-Investigator, JUICE Plasma Environment Package (PEP); JUICE J-MAG; JUICE RPWI
- Team Member, Cassini Magnetosphere and Plasma Science IDS Team
- Member, Magnetosphere Working Group of the EJSM-JGO mission

Relevant Publications:

1. **Jia, X.**, Satellites' magnetotails, *AGU Geophysical Monograph Series: Magnetotails in the Solar System*, in press, 2014.
2. Kivelson, M. G, and **X. Jia**, An MHD model of Ganymede's mini-magnetospehre suggests that the heliosphere forms in a sub-Alfvénic flow, *J. Geophys. Res.*, doi: 10.1002/2013JA019130, 2013.
3. McGrath, M. A., **X. Jia**, K. Retherford, P. D. Feldman, D. F. Strobel, and J. Saur, Aurora on Ganymede, *J. Geophys. Res.*, doi:10.1002/jgra.50122, 2013.
4. **Jia, X.** and M. G. Kivelson, Driving Saturn's magnetospheric periodicities from the atmosphere/ionosphere: Magnetotail response to dual sources, *J. Geophys. Res.,* doi:10.1029/2012JA018183, 2012.
5. **Jia, X.,** et al., Magnetospheric configuration and dynamics of Saturn's magnetosphere: A global MHD simulation, *J. Geophys. Res.*, doi:10.1029/2012JA017575, 2012.
6. **Jia, X.,** M. G. Kivelson and T. I. Gombosi, Driving Saturn's magnetospheric periodicities from the atmosphere/ionosphere, *J. Geophys. Res.*, doi:10.1029/2011JA017367, 2012.
7. Khurana, K. K., **X. Jia**, M. G. Kivelson, F. Nimmo, G. Schubert and C. T. Russell, Evidence of a global magma ocean in Io's interior, *Science*, 332: 1186-1189, doi:10.1126/science.1201425, 2011.
8. **Jia**, **X.**, R. J. Walker, M. G. Kivelson, K. K. Khurana and J. A. Linker, Dynamics of Ganymede's magnetopause: Intermittent reconnection under steady external conditions, *J. Geophys. Res.,* Vol. 115, A12202, doi:10.1029/2010JA015771, 2010.
9. **Jia**, **X.**, R. J. Walker, M. G. Kivelson, K. K. Khurana and J. A. Linker, Properties of Ganymede's Magnetosphere inferred from improved three-dimensional MHD simulations, *J. Geophys. Res.*, doi: 10.1029/2009JA014375*,* 2009.
10. **Jia**, **X.**, M. G. Kivelson, K. K. Khurana and R. J. Walker, Magnetic fields of the satellites of Jupiter and Saturn, *Space Sci. Rev.*, doi:10.1007/s11214-009-9507-8, 2009. Also in the book "*Planetary Magnetism*" by Springer.
11. Olsen, N., K.-H. Glassmeier and **X. Jia**, Separation of the magnetic field into external and internal parts, *Space Sci. Rev.*, doi:10.1007/s11214-009-9563-0, 2009. Also in the book "*Planetary Magnetism*" by Springer.
12. **Jia, X.**, R. J. Walker, M. G. Kivelson, K. K. Khurana and J. A. Linker, Three dimensional MHD simulations of Ganymede's magnetosphere, *J. Geophys. Res.*, Vol. 113, A06212, doi:10.1029/2007JA012748, 2008.

Luke Moore
Curriculum Vitae

Research Scientist
Boston University
Center for Space Physics

725 Commonwealth Ave. Rm. 406
Boston, MA 02215
617-353-7410 ~ moore@bu.edu

Education

2007/2002	Ph.D./M.A.	Astronomy	Boston University
2000	B.S.	Astronomy, Physics	University of Arizona

Appointments

2011 – present	Research Scientist, Center for Space Physics	Boston University
2007 – 2011	Research Associate, Center for Space Physics	Boston University

Professional Service

2008 – present NASA External (MDAP, PATM, Outer Planets), Panel (PAST, CDAP, NESSF) and PDS Referee

2004 – present Journal Referee (JGR, PSS, GRL, Icarus)

Selected Grant Funding

2014 – 2017 NASA Planetary Astronomy Program (PAST), PI
The Dominance of Saturn's Atmosphere by Ring-Rain: Implications for Energy Balance, Chemistry and Ring System Evolution

2013 – 2016 NASA Planetary Atmospheres Program (PATM), PI
Vibrational Distributions of Molecular Hydrogen in the Upper Atmospheres of Jupiter and Saturn

2013 – 2016 NASA Cassini Data Analysis and Participating Scientists (CDAPS), PI
Diurnal Variation of the Saturn Ionosphere

2010 – 2012 NASA Cassini Data Analysis Program (CDAP), Co-I / PI
Low-Altitude Structuring in the Saturn Ionosphere

Selected Publications

Moore, L., et al., Saturn Ring Rain: Water Influx into Saturn's Atmosphere, *Icarus*, submitted, 2014.
O'Donoghue, J., et al., Conjugate observations of Saturn's H_3^+ aurorae, *Icarus*, 229, 214-220, 2014.
Müller-Wodarg, I.C.F., et al., Magnetosphere-atmosphere coupling at Saturn, *Icarus*, 221, 481-494, 2012.
Moore, L., et al., Diurnal variation of electron density in Saturn's ionosphere, *Icarus*, 221, 508-516, 2012.
Ray, L.C., et al., Characterizing the limitations to magnetosphere-ionosphere coupling in Saturn's middle magnetosphere, *J. Geophys. Res.*, doi:10.1029/2011JA017211, 2012.
Galand, M., et al., Response of Saturn's auroral ionosphere to electron precipitation: electron density, electron temperature, and electrical conductivity, *J. Geophys. Res.*, doi:10.1029/2010JA016412, 2011.
Fischer, G., et al., Peak electron densities in Saturn's ionosphere derived from the low-frequency cutoff in Saturn lightning, *J. Geophys. Res.*, 116, A04315, doi:10.1029/2010JA016187, 2011.
Moore, L., et al., Latitudinal variations in Saturn's ionosphere, *J. Geophys. Res.*, 115 A11317, 2010.
Moore, L., et al., Response of Saturn's ionosphere to solar radiation, *Plan.Space Sci.*, 57, 14-15, 1699-1705, 2009.
Nagy, A.F., et al., Upper atmosphere and ionosphere of Saturn, In: *Saturn from Cassini-Huygens*, M.K. Dougherty, L.W. Esposito, S.M. Krimigis (eds.). New York: Springer. 181-202, 2009.
Galand, M., et al., Solar primary and secondary ionization at Saturn, *J. Geophys. Res.*, 114, A6, A06310, 2009.
Moore, L., et al., Plasma temperatures in Saturn's ionosphere, *J. Geophys. Res.*, 113, A10306, 2008.
Moore, L., and M. Mendillo, Are depletions in Saturn's ionosphere caused by explosive surges of water from Enceladus?, *Geophys. Res. Lett.*, 34, L12202, 2007.
Smith, C., et al., An unexpected cooling effect in Saturn's upper atmosphere, *Nature*, 445, 399-401, 2007.
Moore, L., et al., Cassini radio occultations of Saturn's ionosphere, *Geophys. Res. Lett.*, 33, L22202, 2006.
Moore, L. and M. Mendillo, Ionospheric contribution to Saturn's inner plasmasphere, *J. Geophys. Res.*, 110, A05310, doi:10.1029/2004JA010889, 2005.
Moore, L., et al., Modeling of global variations and in Saturn's ionosphere, *Icarus*, 172, 503-520, 2004.

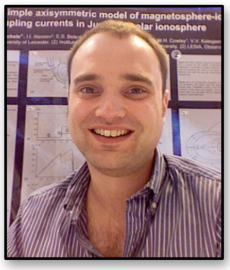
Jonathan Nichols, PhD MPhys (Hons) FRAS

Personal details

Address:
Department of Physics & Astronomy
University of Leicester
University Road
Leicester
LE1 7RH
UK

Tel: +44 (0)116 252 5049
Fax: +44 (0)116 252 3555
E-mail: jdn@ion.le.ac.uk

Nationality: British
Gender: Male
Date of Birth: 30/08/1979



Research interests

Auroras and magnetospheric dynamics of the outer planets and their satellites, extra-solar planets, and ultra-cool dwarfs

Awards

2011: Science and Technology Facilities Council (STFC) Advanced Fellowship
1997: Leicester Space Centre Scholarship

Employment

2013 - present: Lecturer in Physics and Astronomy
2011 - 2016: STFC Advanced Fellow in the auroras of the outer planets[1]
2008 - 2011: Research associate in the auroras of the outer planets[1]
2006-2008: Research associate in the auroras of the outer planets[2]
2004-2006: Research associate in the plasma environments of the outer planets[1]

(1): Radio and Space Plasma Physics Group, University of Leicester, Leicester, UK
(2): Center for Space Physics, Boston University, Boston, MA, USA

Higher Education

University of Leicester, 1997-2004:
2004: PhD Magnetosphere-ionosphere coupling currents in Jupiter's middle magnetosphere (Supervisor: S. W. H. Cowley)
2001: MPhys Physics with Space Science and Technology, 1st class

Scientific responsibilities

PI of HST Programs 11566, 11984, 12176, 13328, 13329, Co-I of HST Programs 10862, 12235, 12883, 13396.
Team Leader of International Space Science Institute (ISSI) International Team "The auroras of the outer planets", 2009 – 2011
Associate Member of the Planets Working Group in the LOFAR Transients Key Project (PI: P. Zarka)

Professional experience and skills

Theoretical modelling, analysis of HST ACS images, Cassini MAG, CAPS and RPWS data
Programming in Python, IDL, Mathematica, LaTeX (expert); C/C++, FORTRAN, HTML (proficient)
Experience with Mac OS X, *NIX, and Windows. Excellent literacy and numeracy.

Selected refereed publications

Nichols, J. D., et al. (2012). Origin of electron cyclotron maser induced radio emissions at ultracool dwarfs: magnetosphere–ionosphere coupling currents, Ap. J., 760:59 (9pp)
Nichols, J. D. (2011a). Magnetosphere-ionosphere coupling at Jupiter-like exoplanets with internal plasma sources: implications for detectability of auroral radio emissions. Mon. Not. R. Astron. Soc., 414, 2125—2138.
Nichols, J. D. (2011b). Magnetosphere-ionosphere coupling in Jupiter's middle magnetosphere: computations including a self-consistent current sheet magnetic field model. J. Geophys. Res., 116, A10232.
Nichols, J. D., et al. (2010b), Variation of Saturn's UV aurora with SKR phase. Geophys. Res. Lett., 37, L15102.
Nichols, J. D., et al. (2009a), Saturn's equinoctial auroras, Geophys. Res. Lett., 36, L24102.
Nichols, J. D., et al. (2008), Oscillation of Saturn's southern auroral oval, J. Geophys. Res., 113(A12), 11205.
Nichols, J. D., E. J. Bunce, J. T. Clarke, S. W. H. Cowley, J.-C. Gérard, D. Grodent, and W. R. Pryor (2007). Response of Jupiter's UV auroras to interplanetary conditions as observed by the Hubble Space Telescope during the Cassini flyby campaign. J. Geophys. Res., 112(A11), A02203.
Nichols, J. D. and S. W. H. Cowley (2004), Magnetosphere-ionosphere coupling currents in Jupiter's middle magnetosphere: effect of precipitation-induced enhancement of the ionospheric Pedersen conductivity, Ann. Geophys., 22, 1799–1827.

Licia C. Ray Revised: March 24, 2014

CONTACT INFORMATION

Department of Physics and Astronomy
University College London
Gower Place
LONDON, UK WC1E 6BT

Phone: +44 (0)20 7679 2446
Fax: +44 (0)20 7679 7153
E-mail: licia.ray@ucl.ac.uk

SCIENTIFIC INTERESTS

- Magnetosphere - ionosphere - thermosphere coupling at Jupiter and Saturn, with a focus on how angular momentum is exchanged between the planetary atmosphere and internal plasma disc
- Auroral electrodynamics: What magnetospheric processes drive the auroral structures observed at Saturn and Jupiter? How can we relate these to ionospheric flows?

EDUCATION

University of Colorado, Boulder, Colorado USA
Ph.D., Astrophysical and Planetary Sciences, August 2010
- Dissertation Topic: "The Impact of Field-Aligned Potentials on Jupiter's Auroral Emission"

M.S., Astrophysical and Planetary Sciences, May 2006
- Thesis Topic: "Modelling the Io-related DAM Emission by Modifying the Beaming Angle"

Boston University, Boston, Massachusetts USA
B.A., Astronomy and Physics, Cum Laude, May 2003

EMPLOYMENT

May 2012 – Present NSF International Research Fellow at University College London
March 2011 – March 2012 Research Associate at Imperial College London
August 2010 – March 2011 Research Associate at University of Colorado, Boulder
August 2007 – July 2010 NASA Earth Space Science Fellow at University of Colorado, Boulder

AWARDS

2011: National Science Foundation International Research Fellowship
2009: American Geophysical Union Outstanding Student Poster Award
2007: NASA Earth Space Science Fellowship
2006: American Geophysical Union Outstanding Student Poster Award

PROFESSIONAL SERVICE AND AFFILIATIONS

2013, 2014: EPSC Session Co-Convener, *Aeronomy of giant planets*
2012: AGU Session Co-Convener, *Magnetospheric processes and dynamics at the giant planets*
2012-2013: Member, ISSI team on Comparative Jovian Aeronomy
2012: Member, ISSI workshop on Giant Planet Magnetodiscs and Aurorae
2011 - present: Journal Referee (JGR, PSS, SSR, GRL)
2011 - present: Member, Royal Astronomical Society
2003 - present: Member, American Geophysical Union

RELEVANT PUBLICATIONS

L. C. Ray, N. A. Achilleos, M. F. Vogt, J. N. Yates, "Local time variations in Jupiter's magnetosphere-ionosphere coupling system", *J. Geophys. Res.*, submitted.

L. C. Ray, N. A. Achilleos, J. N. Yates, "Including field-aligned ptentials in the coupling between Jupiter's thermosphere, ionosphere, and magnetosphere", *Planetary & Space Sciences*, submitted.

L. C. Ray, M. Galand, P. A. Delamere, B. L. Fleshman, "Current-voltage relation for the saturnian system", *J. Geophys. Res., 118*, 2013.

L. C. Ray, M. Galand, L. E. Moore, B. L. Fleshman, "Characterising the limitations to the coupling between Saturn's ionosphere and middle magnetosphere", *J. Geophys. Res., 117*, 2012

L. C. Ray, R. E. Ergun, P. A. Delamere, F. Bagenal, "Magnetosphere-Ionosphere Coupling at Jupiter: A parameter space study", *J. Geophys. Res., 117*, 2012

L. C. Ray, R. E. Ergun, P. A. Delamere, F. Bagenal, "Magnetosphere-Ionosphere Coupling at Jupiter: A parameter space study", *J. Geophys. Res., 117*, 2010

L. C. Ray, R. E. Ergun, P. A. Delamere, F. Bagenal, "Magnetosphere-Ionosphere Coupling at Jupiter: Effect of field-aligned potentials on angular momentum transport", *J. Geophys. Res., 115*, 2010

Curriculum Vitae – JOACHIM SAUR

Prof. Dr. Joachim Saur	Mail address:
Professor for Geophysics	Institute of Geophysics and Meteorology
Institute of Geophysics and Meteorology	University of Cologne
University of Cologne	Albertus-Magnus-Platz
	50923 Koeln, Germany
	Tel: +49-221-470-2310
	Fax: +49-221-470-5198
	saur@geo.uni-koeln.de

Citizenship: Germany

Education

- Ph.D. February 2000 (highest honors) Geophysics, University of Cologne, Germany
  Title: Plasma Interaction of Io and Europa with the Jovian Magnetosphere
- Physics, University of Stuttgart and University of Cologne, Germany,
  Diplom in March 1995

Professional Experience

2005	-	present	Full Professor for Geophysics, University of Cologne, Germany
2003	-	2005:	Senior Research Scientist, JHU/Applied Physics Laboratory, USA
2001	-	2002:	Postdoctoral Fellow, Johns Hopkins University, Baltimore, USA
2000	-	2001:	Postdoctoral Researcher, Observatoire de la Côte d'Azur, Nice, France

Research Interests

Space physics and planetary sciences, including planetary moons, extra-solar planets, magnetospheres, aurorae, and turbulence in space plasmas.

Professional Affiliations

American Geophysical Union
Division of Planetary Sciences of the American Astronomical Society
Deutsche Geophysikalische Gesellschaft

Mission Participation, Science Projects

Hubble Space Telescope, PI in Cycle 16 (2008), Cycle 18 (2010, 2011), Cycle 20 (2012), Co-I in several Cycles (2007, 2009, 2013, 2014)
Collaborator on NASA's JUNO mission (a Jupiter polar orbiter).
Co-I on Esa's JUICE mission (Juiter Icy Moons Explorer) for RWPI and J-MAG instruments.

Services

Hubble Space Telescope, Time Allocation Committee, Cycle 14 (2005)
European Southern Observatory, Observing Programmes Committee, Cycles 82, 83 (2008)
ALMA, Time Allocation Committee, Cycle 1, 2 (2012, 2014)
Department Chair Geosciences, University of Cologne (2008-2009, 2013-2015).
Associated Editor, Journal of Geophysical Research, Space (2008-2011)
Head of Planet Section of German Arbeitsgemeinschaft Extraterrerstr. Forschung (2009-2014)

Publication

More than 50 peer reviewed publications on the magetospheres and satellites of Jupiter and Saturn

Curriculum Vitae

(Last updated: March 21, 2014)

Name: Chihiro TAO
Work: Institut de Recherche en Astrophysique et Planétologie (IRAP)
E-mail: chihiro.tao@irap.omp.eu
Work Telephone: +33 (0)561 55 66 81
Work Address: 9 avenue du Colonel Roche, 31028, Toulouse, France
Nationality: Japanese

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

- 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

Highlight of my relevance to the ISSI team

- I have developed original models (auroral coupling [Tao et al., 2009; 2010], thermosphere dynamics [Tao et al., 2009], auroral electron precipitation [Hiraki and Tao, 2008], and auroral emission models [Tao et al., 2011; 2012]), which will bring insight in comparison by their uniqueness.
- I am interested in the coupling models to improve boundary condition [e.g., Tao et al., 2009].
- For "Topic 3" I have experience on data assimilation applied to solar wind, and on estimation of observable parameter (auroral emission) [Tao et al., 2011] to bridge model and observation studies

Tao, C., S. V. Badman, T. Uno, and M. Fujimoto (2012), On the feasibility of characterizing Jovian auroral electrons, via H3+ infrared line-emission analysis, Icarus, 221, 236-247.

Tao, C., S. V. Badman, and M. Fujimoto (2011), UV and IR auroral emission model for the outer planets: Jupiter and Saturn comparison, ICARUS, 213, 581-592.

Tao, C., H. Fujiwara, and Y. Kasaba (2010), Jovian magnetosphere-ionosphere current system characterized by diurnal variation of ionospheric conductance, Planet. Space Sci., 58, 351-364.

Tao, C., H. Fujiwara, and Y. Kasaba (2009), Neutral wind control of the Jovian magnetosphere-ionosphere current system, J. Geophys. Res., 114, A08307, doi:10.1029/2008JA013966.

Hiraki, Y., and C. Tao (2008), Parameterization of ionization rate by auroral electron precipitation in Jupiter, Ann. Geophys., 26, 77-86.

Robert M. Winglee

Professor, Chair, Earth and Space Sciences
Director, Washington NASA Space Grant
Department of Earth and Space Sciences, Box 351310
University of Washington, Seattle, WA 98195-1310; Ph: 1-206-685-8160

Professional Preparation.

Ph. D., University of Sydney, 1984; B. Sc. (Hons.), University of Sydney, 1980

Appointment. 7/05—present: Chair, Department of Earth and Space Sciences, Univ. of Washington; 7/07 – present: Director, Washington NASA Space Grant Consortium

Awards. DISCOVER Magazine Awards for Technological Innovation, sponsored by the Christopher Columbus Fellowship Foundation, Aerospace category, 2001.

Students Supervised

PhD's: M. McKean, Z. Zhu, R. Elsen, A. Goodson, M. Wilber, S. Matt, E. Harnett*, T. Ziemba, L Giersch, C. Paty*, J. Prager, D. Snowden*, A. Kidder*, M. Cash*

Masters: Q. Li, D. Collin, M. Bartone, D. Peters, Moon-Young Choi*, I. Slobodov, I. Johnson

Current Graduate Students B. R. Roberson (Earth and Space Sciences), I. Johnson (Aeronautics and Astronautics) , Nao Murakami (Aeronautics and Astronautics) *, N. Becker (Earth and Space Sciences)

Undergraduate Students Mentored in Research

J. Hughes, K. Princehouse. L. Winstrom, B. Warrick, M. Bentz*, E. Suthers, H. Cummings*, J. Cascarden, L. Rachmeler*, M. Nivala, T. Schnackenberg, S. Isley, A. Stickle*, E. Bell*, G. Quetin, J. Trescott, J. DeBoever*, J. Porter*, J. Duncan, S. Campbell, A. Bourdages, Keith Cowan, Julian Picard, Deven Bryant, Sr., Theodore Newell, Reece Beigh, Tia Lerud*, Jamie Wadlock*, Nadia Ifland*, Chad Truitt, Craig Fould * Women

Published Over 120 papers.

Winglee, R. M., W. K. Peterson, A. W. Yau, E. Harnett, and A. Stickle, Model/Data Comparisons of ionospheric outflow as a function of invariant latitude and magnetic local time, *J. Geophys. Res*., 113, A06220, doi:10.1029/2007JA012817, 2008.

Winglee, R. M., D. Snowden, and A. Kidder, Modification of Titan's Ion Tail and the Kronian Magnetosphere: Coupled Magnetospheric Simulations, *J. Geophys. Res*., *114*, A05215, doi:10.1029/2008JA013343, 2009.

Snowden, D., and R. M. Winglee, Titan at the Edge I: Titan's interaction with Saturn's magnetosphere in the pre-noon sector, *J. Geophys. Res*., 116, A08229, doi:10.1029/2011JA016435, 2011.

Winglee, R. M., Influence of heavy ionospheric ions on substorm onset, *J. Geophys. Res*., 116, A11212, doi:10.1029/2011JA016447, 2011.

Kidder, A., C. S. Paty, R. M. Winglee and E. M. Harnett, External Triggering of Plasmoid Development at Saturn, *J. Geophys. Res*., 117, A07206, doi: 10.1029/2012JA017625, 2012.

Japheth Nesta Yates

Address

Space and Atmospheric Physics
Imperial College London
South Kensington, London, SW7 2AZ, UK

Telephone: +44 (0)20 7594 1155
Email: japheth.yates@imperial.ac.uk

Research Interests

Comparative planetology, in particular

- Gas giant magnetosphere-ionosphere-thermosphere (MIT) coupling: How does the coupled MIT system vary with solar wind conditions? Can we explain the high thermospheric temperatures observed at Jupiter and Saturn?
- Periodicities at Saturn.
- The Jovian and Kronian magnetic and plasma environment.

Employment

Postdoctoral research associate — **Sept 2013 – Present**
Imperial College, London, UK

Postdoctoral research associate — **Feb 2013 – Aug 2013**
University College London, London, UK

Education

University College London
PhD in Astrophysics — **Sept 2009 – Mar 2013**
Title: Influence of solar wind on the Jovian thermosphere.
Physics MSci – First Class Honours — **Sept 2004 – June 2008**

Technical skills

Theoretical and numerical modelling; Data analysis; Programming with FORTRAN, C++, Java, Python, OpenMP, MPI, LaTeX and Matlab. Experience with Microsoft Windows, Mac OS X, Linux distributions and High Performance Computing.

Professional Memberships

Fellow of the Royal Astronomical Society.
Member of the European Geosciences Union.
Member of the American Geophysical Union.

Professional Achievements

2013, 2014: Convener of 'Aeronomy of giant planets' session at EPSC.
2013: Invited seminar at University of Leicester (2013).
2012: Invited seminar at Imperial College London.

Selected Publications

1. **Yates, J.**, Achilleos, N., Guio, P., 2012. 'Influence of upstream solar wind on thermospheric flows at Jupiter.' Planetary and Space Science (Special Issue) 61: Surfaces, atmospheres and magnetospheres of the outer planets and their satellites and ring systems: Part VII.
2. **Yates, J.**, Achilleos, N., Guio, P., 2014, 'Response of the Jovian thermosphere to a transient 'pulse' in solar wind pressure', Planetary and Space Science, Volume 91.