Proposal for an ISSI International Team study project:

Heavy ions: their dynamical impact on the magnetosphere

Team leader: Elena Kronberg

1 Abstract

Knowledge about the ion composition in the near-Earth's magnetosphere and plasma sheet is essential for the study of magnetospheric processes and instabilities. The composition of a plasma determines the mass density and plays an important role for fundamental plasma properties such as the Alfvén speed, plasma pressure and consequently the plasma beta.

Ionospheric-origin ions modify the density, temperature and composition of the plasmasheet, the main reservoir of magnetospheric plasma. The presence of ionospheric-origin heavy ions, in particular O+, influences reconnection rates and the formation of Kelvin-Helmholtz instabilities, important drivers of global magnetospheric dynamics on which other systems (ring current, radiation belts) are dependent. The radiation belts are of foremost importance for space weather studies as their dynamical changes can lead to the damage of satellites. Modeling the dynamics of the radiation belt includes the dynamics of the ring current and must account for the contribution of heavy ions. Indeed, plasma sheet particles drift Earthward and populate the ring current, which influences the transport of the radiation belts. Consequently, ionospheric heavy ions lead to changes of the ring current and of the radiation belts.

It is a challenging task to include the ionospheric ion contribution in numerical studies of the magnetotail, ring current and radiation belt. Estimating the ion composition is important for defining the boundary conditions in such simulations. Therefore, knowledge of the ion abundance ratio and its dependence on the solar wind and magnetospheric conditions are required. It is also important to know in which form the modelers need the results of data analysis in order to incorporate them into their models. The improvement of numerical models via verification against data is an important activity towards better understanding of near-Earth space weather.

We propose an ISSI team to gather observations and modeling specialists combine the best databases (Cluster) and models, and investigate the role of the heavy ion contribution on the dynamics of the near-Earth magnetosphere. It is the right moment to bring together experts from these different fields to obtain a vastly improved understanding of the near-Earth magnetospheric dynamics as: (1) We have already collected the data from one full solar cycle; (2) Models rapidly developing the ability to account for these heavy ions and thus require verification; (3) It links well with the soon-to-be-launched (September 2012) Radiation Belts Storm Probes (RBSP) mission. Therefore, these forthcoming observations can be compared and verified with rich, well-calibrated Cluster observations. The work of this team will yield three essential products that will be made available to the whole community: complete composition data sets that span wide spatial and energy regimes, validation of heavy ion capabilities of widely used numerical models, and a peer-reviewed journal special section that chronicles our scientific findings.

2 Scientific Background

The main source of oxygen in the terrestrial magnetosphere is thought to be the ionosphere (e.g., *Yau et al.*, 1984; *Cully et al.*, 2003; *Moore and Horwitz*, 2007; *Kitamura et al.*, 2010), where oxygen ions are accelerated upward by several processes, e.g. parallel electric fields. The ionospheric ions are accelerated either in cusp/cleft region and then convect across the polar cap and into the lobe (*Kistler et al.*, 2010) or they come from the nightside aurora, which provides a fast feeding of $O+$ ions in the near-Earth plasma sheet during substorm expansion phase (*Daglis and Axford*, 1996). The kinetic energy of upflowing ions is typically a few tens of eV, whereas typical plasma sheet energies are much higher (e.g. *Lennartsson and Shelley*, 1986). Centrifugal acceleration will accelerate the particles as they travel tailward along field lines (e.g., *Cladis*, 1986; *Nilsson et al.*, 2010), but the most significant energization will take place after the particles enter the plasma sheet.

There are at least 3 types of ion acceleration mechanisms in the plasma sheet of the magnetotail:

1. Speiser non-adiabatic acceleration by a quasi-stationary dawn-dusk electric field was proposed by (*Speiser*, 1965). *Büchner and Zelenyi* (1989) studied kinetic features of non-adiabatic particle dynamics in the current sheet and demonstrated that particles can be either stochastically energized in the region of weak magnetic field or experience direct acceleration along magnetic field lines in spatially localized regions uniformly distributed across the tail. Later these features were reproduced in large-scale kinetic simulations of non-adiabatic ion dynamics in the magnetotail current sheet (*Ashour-Abdalla et al.*, 1993).

2. Induction electric fields are discussed by (e.g., *Delcourt*, 2002). *Hoshino et al.* (1998) reported the generation of dawn-dusk electric fields with amplitudes of several mV/m in the magnetic reconnection region. Such induced electric fields may accelerate ions to energies well exceeding the typical value of potential drop across the tail (higher than 100 keV). Recent results (*Ono et al.*, 2009) also indicate that induced electric fields associated with magnetic fluctuations during dipolarization may be responsible for the acceleration.

3. Betatron energization (e.g., *Tverskoy*, 1972) occurs due to the increase of magnetic field magnitude and shortening of the field line. Betatron energization always exists and accelerates ions in the quiet magnetotail. During disturbed times, along dipolarization fronts, such acceleration is especially effective. However, in such cases of dipolarization, the acceleration by inductive electric fields due to the change of the magnetic field configuration takes also place.

Once in the plasma sheet, the ionospheric-origin population has a cascading set of effects on the rest of the magnetosphere. Particles accelerated in the plasma sheet drift Earthward and populate the ring current. Here, heavy ionospheric particles can carry the bulk of the plasma pressure (*Nosé et al.*, 2005), changing the background magnetic field, densities, temperature and convection electric field in the ring current region (*Welling et al.*, 2011). These changes the radiation belts, a key region of space weather studies, as their dynamical changes can lead to spacecraft damage and loss. The radiation belt dynamics forecasting models include, as a part of its chain, the dynamics of the ring current. It is still a challenging task to include the heavy ion contribution in the numerical studies of the ring current (e.g., *Glocer et al.*, 2009; *Welling et al.*, 2011) or radiation belt modeling itself (*O'Brien*, 2005). The knowledge of the ion composition is important for defining the boundary conditions in such models.

Knowledge about the ion composition in the near-Earth magnetosphere is also essential for the study of plasma instabilities. The composition determines the mass density and plays an important role for fundamental plasma properties such as the Alfvén speed, plasma pressure and consequently the plasma beta. Since the mass density also enters the expression for dispersion relations, e.g. the Rayleigh-Taylor, ion tearing mode, and Kelvin-Helmholtz instabilities, a change in composition also leads to changes in the instability threshold. The ion composition will affect the generation of plasma waves. For example, the knowledge of the ring current plasma composition helps to determine the precise spectrum of the electromagnetic ion cyclotron (EMIC) wave instabilities and survey of wave growth (*Mace et al.*, 2011). Also, reconnection rate at the dayside magnetosphere depends on the plasma mass density (*Borovsky et al.*, 2008).

What has been done before? *Hamilton et al.* (1988) implementing AMPTE particle measurements has shown an event during which O^+ dominates H^+ the ring current during a large magnetic storm. A later study by *Daglis et al.* (2000) demonstrated a connection between O^+ (50-426 keV, measured by CRRES) enhancements and storm/substorm activity in the inner magnetosphere at ~7 L.

The previous studies have diverse conclusions about the origin of the energetic heavy ions in the magnetosphere. *Nosé et al.* (2000) used Geotail/EPIC measurements of energetic (60 keV to 3.6 MeV) ion flux in order to state that the strong increase of energetic oxygen ions is due to the local magnetic field reconfiguration, namely dipolarizations and not magnetotail reconnection. In later case studies, *Nosé et al.* (2001, 2003, 2005) used energetic (9-210 keV) particle flux data from Geotail and concluded that the enhanced ratio of O^+/H^+ during storms was due to ion energization by the dawn-to dusk convection electric field in a mass-dependent way. *Ono et al.* (2009) used 10 years of Geotail EPIC data to argue that it was the magnetic fluctuations associated with dipolarization that caused the acceleration.

The effectiveness of the energization processes acting on heavy ions remains unknown; models and observations yield varying answers. What is the cause of the O^+ enhancement during substorms? *Fok et al.* (2006) using test particles in MHD simulations, concluded that this are preexisting oxygen ions energized in the plasma sheet during substorms. Multi-fluid/multi-scale simulations by *Winglee and Harnett* (2011) show that heavy ionospheric ions can contribute nearly 50% of the total energy density at the inner edge of the plasma sheet already prior to substorm onset (see Figure 1). This leads to over pressurization and dipolarization together with onset and increases in the nightside auroral current systems. Also simulations by *Ashour-Abdalla et al.* (2009) show that ionospheric ions contribute significantly to the cross-tail current prior to substorm onset.

Recent statistical studies on the ion composition reveal dependencies which are useful for modeling. For example, *Nosé et al.* (2009) used the same Geotail data for more than 16 years, covering distances from $-100R_E < X_{GSM} < -8R_E$ to study the suprathermal ion composition in the plasma sheet. They investigated the correlation between the O^+/H^+ ratio with solar activity using the F10.7 index and with the geomagnetic activity using the Kp index. They concluded that the physical processes in the plasma sheet are expected to be very diverse during solar activity minimum and solar maximum, as the different ion plasma mass during these regimes leads to the different Alfvén velocity. Also the O^+ and H^+ bulk content (1-40 keV/e, Cluster/CIS) in the plasma sheet within 15-19 R_E was studied as function of the solar activity and the geomagnetic activity (*Mouikis et al.*, 2011).

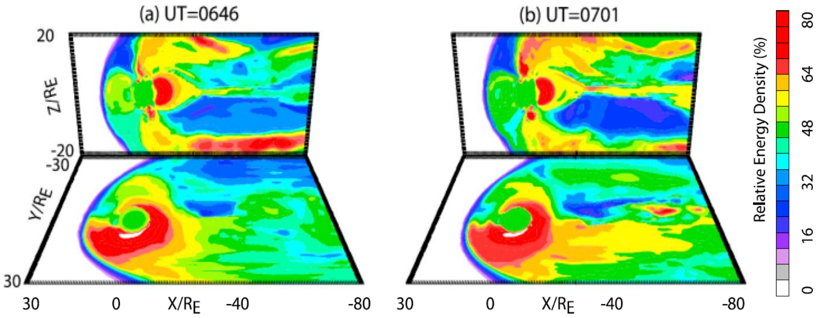

Figure 1: Evolution of the relative O+ energy density in the noonmidnight meridian and equatorial plane prior to the substorm onset. At the inner edge of the plasma sheet freshly injected O^+ contributes a majority of the energy (taken from *Winglee and Harnett* (2011)).

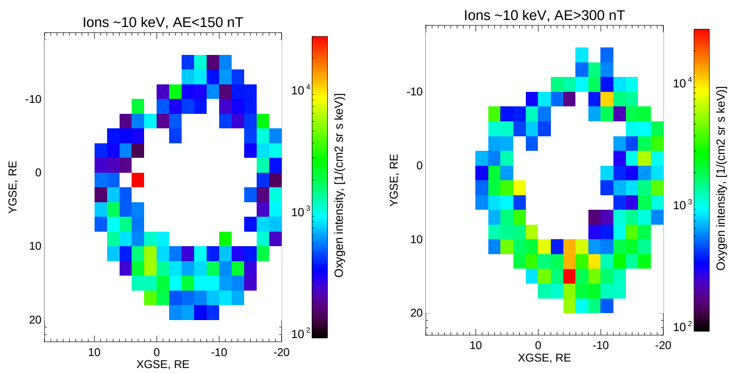

Figure 2: Maps of the oxygen intensities at ∼10 keV versus AE index (taken from Kronberg at al., Oxygen abundance in the near-Earth magnetosphere: Statistical results from 7 years of Cluster observations, submitted to JGR).

3 Goals

The goal of the team is to investigate the role of oxygen in the near-Earth magnetospheric dynamics. The aim is to bring together people working on simulations and on data analysis to examine and re-examine this problem in detail. Long experience shows that it is not easy to combine models and observations and get consistent results. The data show particular features and the models cannot always predict them, and similarly, we do not always see what models predict. One can often hear from modelers: *how could we integrate your data in our model?* Therefore, the major purpose is to merge the observations and models and mutually become richer.

In this team we would like to focus on composition data form Cluster. Why do we choose Cluster? Limiting the scope to a single data set yields a manageable problem and a manageable team size. Cluster is an European mission that has data for more than 11 years, covering a full solar cycle. It has 4 satellites that fly in the tetrahedron configuration. The mission has a polar orbit, allowing for coverage of the higher-latitudes. It covers the magnetotail, inner magnetosphere and radiation belts. It provides particle data with high time resolution, mass resolution and pitch-angle information. The set covers a broad, previously unattainable energy range of 30 eV to 948 keV. Because it is a contemporary mission, accurate solar-terrestrial coupling parameters are available throughout the growing data set.

Using these powerful data, we plan to investigate how the transport of the ionospheric ion population from the tail to the near-Earth plasma sheet depends on the geomagnetic and solar wind activity and to which extent new observational results can be implemented in the models. The Cluster Ion Spectrometer (CIS, see *Rème et al.*, 2001) and the Research with Adaptive Particle Imaging Detector (RAPID, see *Wilken et al.*, 2001) teams developed data calibration techniques that provide us with excellent particle data in all these regions (I. Dandouras, L. Kistler, E. Kronberg). Though we have a huge database of observations that satellites cover the regions from the magnetotail to inner radiation belts, it is hard to interpret the data alone without support from models and theory.

For example, the analysis of data shows that the dawn-dusk asymmetries strongly depend on the energy and the disturbance level (Kronberg et al., submitted to JGR (see Figure 2), also in Maggiolo, R., L. Kistler: 2D O+ and H+ density profile in the magnetospheric equatorial plane, in preparation). These can be interpreted by comparison with published models. The problem is that modelers run simulations for specific energies and magnetospheric conditions and the results can be very different if the combination of them is not the same as in observations. It works also the other way around, that the models cannot be verified if the data are not the prepared in the way the modelers need them.

Key tasks to be solved:

1. To merge independent particle data bases from CIS and RAPID instruments, in order to have complete pressure measurements that may be dominated by energetic particles during disturbed times. Additionally to obtain detailed temporal and spatial distributions of ions versus energy and species. It is also important to be able to map the data observations to the planes where observation were not frequently made (like equatorial plane) in order to make better comparisons with models (I. Dandouras, L. Kistler, R. Maggiolo, E. Kronberg).

2. To verify the dawn-dusk asymmetries and to obtain the most accurate energy distribution in the near-Earth region including the magnetotail (M. Ashour-Abdalla, large scale kinetic simulations using a three dimensional time dependant model of electric and magnetic fields).

3. To compare the efficiency of the acceleration of different ion species in the magnetotail current sheet by potential (dawn-dusk) and induced electric fields for the magnetic configurations with distant and near-Earth X-line and with presence of magnetic turbulence (E. Grigorenko, large scale kinetic simulations).

4. To check how the loss of the ions at the magnetopause depends on its energy and how the particle energization and transport depends on the disturbance level (D. Delcourt, single-particle trajectory calculations in dynamic reconfigurations of the inner magnetosphere).

5. How the distribution of O+ changes with the solar wind parameters and geomagnetic activity in ring current (D. Welling, Space Weather Modelling Framework, a tool for coupling and synchronizing many different space weather codes).

6. How can O^+ influence the radiation belt dynamics? Although a significant influence of O^+ ions on low frequency plasma modes is well known, satisfactory models which include low energy protons and O^+ ions in the radiation belt dynamics are still not developed. This gap between ring current models and radiation belt models should be filled. The experts in this field are invited to develop ideas on how these can be done (D. Shklyar, Y. Shprits).

In order to be more focused we do not include in the goals collaborations with experts on the ring current model (CRCM); multi-fluid, multi-scale simulations of the magnetosphere; influence of O^+ on reconnection rate; heavy ions and EMIC wave instabilities and many others. However, the outcome of the team work will make these collaborations easier to proceed.

4 Timeliness of the project

Cluster provided a unique sets of particle data, which are from in situ measurements in an ideal plasma laboratory. We have well prepared data bases of the particle data together with solar wind and geomagnetic parameters. Such data sets became available only very recently, because before one had less data coverage and not complete data calibrations. A sophisticated analysis of these data is not only important for magnetospheric physics and space weather but plasma physics in general, as we study how fundamental features of the plasma are influenced by the heavy ions.

There has been not much interactions between modelers and observers so far on this topic. The observers and modelers have to learn about the benefits of their different approaches and to enrich their ability to communicate. We are now well prepared to merge new observations and new simulation tools to improve vitally developing space weather related models and the way the data are prepared to be used for modelling.

The studies related to the radiation belts are highly important now: to enhance the return from the soon to be launched RBSP mission (September 2012) which will be studying the inner magnetosphere and radiation belts. RBSP observations could be compared and verified with rich and well calibrated Cluster observations. This would lead to the higher impact of the excellent Cluster data before community has focused on data from the new mission. It is also important for better visibility of European science in the radiation belts field and space weather.

5 Expected output

The work of this team will provide three essential products that will be made available to the whole community: complete composition data sets that span wide spatial and energy regimes, validation of heavy ion capabilities of widely used numerical models, and a peer-reviewed journal special section that chronicles our scientific findings on the tasks described in Section 3. We anticipate our results will encourage further improvements in collaboration of modelers and data-analysis people also in other magnetospheric regions and including extended data bases. We expect to gain an experience of merging large data bases of particle observations with space weather related models.

6 What is the value of ISSI

Investigation of this problem requires a wide spectrum of knowledge and experience. The opportunity to gather an ISSI team would allow the bringing together of people from different fields, working on different continents, gathering into a focused team. Having the opportunity to conduct two dedicated week-long sessions is very beneficial, as it would allows brainstorming and extended discussions, which can be especially productive when people are from different communities: simulation and data analysis. These sessions will lead to the generation of new ideas. Fundamental progress in this area requires the intimate cooperation of experts that only ISSI can provide. It is not possible to bring together the required expert team without ISSI, because we would never otherwise be able to meet as a group with the time, space and resources to attack this important problem. The previous experience of team-members has shown that ISSI is an extremely effective tool for promoting the necessary cross-fertilization of ideas between researchers in different areas.

7 Team members

We are a well balanced team of experts in observations and simulations who wishes come together for the fruitful collaboration.

1.	Prof. Maha Ashour-Abdalla	University of California, Los Angeles	USA	analytic theory and simulations of the plasma acceleration
2.	Dr. Iannis Dandouras	Institut de Recherche en Astrophysique et Planétologie	France	Cluster bulk plasma data
3.	Dr. Dominique Delcourt	Laboratoire de Physique des Plasmas	France	theoretical modelling of ion acceleration
4.	Dr. Elena Grigorenko	Space Research Institute	Russia	ion acceleration modelling
5.	Prof. Lynn Kistler	University of New Hampshire	USA	Cluster bulk plasma data
6.	Dr. Elena Kronberg	Max Planck Institute for Solar System Research	Germany	Cluster energetic particle observations
7.	Dr. Romain Maggiolo	Institut d'Aeronomie Spatiale de Belgique	Belgium	Cluster bulk plasma data
8.	Dr. David Shklyar	Space Research Institute	Russia	radiation belt modelling
9.	Dr. Yuri Shprits	University of California, Los Angeles	USA	radiation belt modelling
10.	Dr. Daniel Welling	University of Michigan	USA	global MHD modelling of the ring current

Young scientists will be contacted if the proposal is accepted.

8 Schedule

We would like to have two one-week meetings: one in winter 2012/2013 and one in mid-2013. The goals of the first meeting are to show the available data to modelers and show questions which appeared during data analysis. The modelers will show to observers their latest developments. This will be followed by discussions culminating in the identification of tasks to do in order to implement data to models. We anticipate it will then be advantageous to split into groups and work on the detailed studies. At the end of the first meeting with new relationships forged and the conversation on combining our efforts well under way, we will summarize our findings and formulate a relevant plan of work to combine data and models, home work for data preparation and model adjustments. At the second meeting, we will discuss progress, continue to work in groups on the detailed studies and finalize the papers.

9 Financial support and Required facilities

We apply to ISSI for the financial support to cover accommodation and per diem for each member of the ISSI team and the travel costs for the team leader. The other team members will cover their travel expenses to/from Bern from their own research budgets.

We require a meeting room to accommodate 10 people with projector and screen. Additionally wireless internet and cable network access for notebook computers.

Appendicies

A References

Ashour-Abdalla, M., J. P. Berchem, J. Buechner, and L. M. Zelenyi (1993), Shaping of the magnetotail from the mantle - Global and local structuring, , *98*, 5651–5676, doi:10.1029/92JA01662.

Ashour-Abdalla, M., J.-M. Bosqued, M. El-Alaoui, V. Peroomian, M. Zhou, R. Richard, R. Walker, A. Runov, and V. Angelopoulos (2009), A simulation study of particle energization observed by THEMIS spacecraft during a substorm, *J. Geophys. Res.*, *114*, A09204, doi:10.1029/2009JA014126.

Büchner, J., and L. M. Zelenyi (1989), Regular and chaotic charged particle motion in magnetotaillike field reversals. I - Basic theory of trapped motion, *J. Geophys. Res.*, *94*, 11,821–11,842, doi:10.1029/JA094iA09p11821.

Borovsky, J. E., M. Hesse, J. Birn, and M. M. Kuznetsova (2008), What determines the reconnection rate at the dayside magnetosphere?, *J. Geophys. Res.*, *113*, A07,210, doi:10.1029/2007JA012645.

Cladis, J. B. (1986), Parallel acceleration and transport of ions from polar ionosphere to plasma sheet, *Geophys. Res. Lett.*, *13*, 893–896, doi:10.1029/GL013i009p00893.

Cully, C. M., E. F. Donovan, A. W. Yau, and H. J. Opgenoorth (2003), Supply of thermal ionospheric ions to the central plasma sheet, *J. Geophys. Res.*, *108*, 1092, doi:10.1029/2002JA009457.

Daglis, I. A., and W. I. Axford (1996), Fast ionospheric response to enhanced activity in geospace: Ion feeding of the inner magnetotail, , *101*, 5047–5066, doi:10.1029/95JA02592.

Daglis, I. A., Y. Kamide, C. Mouikis, G. D. Reeves, E. T. Sarris, K. Shiokawa, and B. Wilken (2000), “Fine Structure” of the Storm-Substorm Relationship: Ion Injections During Dst Decrease, *Advances in Space Research*, *25*, 2369–2372, doi:10.1016/S0273-1177(99)00525-6.

Delcourt, D. C. (2002), Particle acceleration by inductive electric fields in the inner magnetosphere, *Journal of Atmospheric and Solar-Terrestrial Physics*, *64*, 551–559, doi:10.1016/S1364-6826(02)00012-3.

Fok, M., T. E. Moore, P. C. Brandt, D. C. Delcourt, S. P. Slinker, and J. A. Fedder (2006), Impulsive enhancements of oxygen ions during substorms, *J. Geophys. Res.*, *111*, 10,222, doi:10.1029/2006JA011839.

Glocer, A., G. Tóth, Y. Ma, T. Gombosi, J.-C. Zhang, and L. M. Kistler (2009), Multifluid Block-Adaptive-Tree Solar wind Roe-type Upwind Scheme: Magnetospheric composition and dynamics during geomagnetic storms – Initial results, *J. Geophys. Res.*, *114*, A12203, doi:10.1029/2009JA014418.

Hamilton, D. C., G. Gloeckler, F. M. Ipavich, B. Wilken, and W. Stuedemann (1988), Ring current development during the great geomagnetic storm of February 1986, , *93*, 14,343–14,355, doi:10.1029/JA093iA12p14343.

Hoshino, M., T. Mukai, T. Yamamoto, and S. Kokubun (1998), Ion dynamics in magnetic reconnection: Comparison between numerical simulation and Geotail observations, *J. Geophys. Res.*, *103*, 4509–4530, doi:10.1029/97JA01785.

Kistler, L. M., E. Moebius, B. Klecker, G. Gloeckler, and F. M. Ipavich (1990), Spatial variations in the suprathermal ion distributions during substorms in the plasma sheet, *J. Geophys. Res.*, *95*, 18,871–18,885, doi:10.1029/JA095iA11p18871.

Kistler, L. M., C. G. Mouikis, B. Klecker, and I. Dandouras (2010), Cusp as a source for oxygen in the plasma sheet during geomagnetic storms, *J. Geophys. Res.*, *115*, A03209, doi:10.1029/2009JA014838.

Kitamura, N., et al. (2010), Observations of very-low-energy ($<$10 eV) ion outflows dominated by O^+ ions in the region of enhanced electron density in the polar cap magnetosphere during geomagnetic storms, *J. Geophys. Res.*, *115*, A00J06, doi:10.1029/2010JA015601.

Lennartsson, W., and E. G. Shelley (1986), Survey of 0.1- to 16-keV/e plasma sheet ion composition, , *91*, 3061–3076, doi:10.1029/JA091iA03p03061.

Mace, R. L., R. D. Sydora, and I. Silin (2011), Effects of superthermal ring current ion tails on the electromagnetic ion cyclotron instability in multi-ion magnetospheric plasmas, *J. Geophys. Res.*, *116*, A05,206, doi:10.1029/2010JA016393.

Moore, T. E., and J. L. Horwitz (2007), Stellar ablation of planetary atmospheres, *Reviews of Geophysics*, *45*, 3002, doi:10.1029/2005RG000194.

Mouikis, C. G., L. M. Kistler, Y. H. Liu, B. Klecker, A. Korth, and I. Dandouras (2011), The H+ anf O+ content of the plasma sheet at 15-19 Re as a function of geomagnetic and solar activity, *J. Geophys. Res.*, *115*, A00J16, doi:10.1029/2010JA015978.

Nilsson, H., E. Engwall, A. Eriksson, P. A. Puhl-Quinn, and S. Arvelius (2010), Centrifugal acceleration in the magnetotail lobes, *Annales Geophysicae*, *28*, 569–576, doi:10.5194/angeo-28-569-2010.

Nosé, M., S. Ohtani, A. T. Y. Lui, S. P. Christon, R. W. McEntire, D. J. Williams, T. Mukai, Y. Saito, and K. Yumoto (2000), Change of energetic ion composition in the plasma sheet during substorms, , *105*, 23,277–23,286, doi: 10.1029/2000JA000129.

Nosé, M., S. Ohtani, K. Takahashi, A. T. Y. Lui, R. W. McEntire, D. J. Williams, S. P. Christon, and K. Yumoto (2001), Ion composition of the near-Earth plasma sheet in storm and quiet intervals: Geotail/EPIC measurements, , *106*, 8391–8404, doi:10.1029/2000JA000376.

Nosé, M., R. W. McEntire, and S. P. Christon (2003), Change of the plasma sheet ion composition during magnetic storm development observed by the Geotail spacecraft, *J. Geophys. Res.*, *108*, 1201, doi:10.1029/2002JA009660.

Nosé, M., S. Taguchi, K. Hosokawa, S. P. Christon, R. W. McEntire, T. E. Moore, and M. R. Collier (2005), Overwhelming O^+ contribution to the plasma sheet energy density during the October 2003 superstorm: Geotail/EPIC and IMAGE/LENA observations, *J. Geophys. Res.*, *110*, 9, doi:10.1029/2004JA010930.

Nosé, M., A. Ieda, and S. P. Christon (2009), Geotail observations of plasma sheet ion composition over 16 years: On variations of average plasma ion mass and O^+ triggering substorm model, *J. Geophys. Res.*, *114*, A07,223, doi:10.1029/2009JA014203.

O'Brien, T. P. (2005), A framework for next-generation radiation belt models, *Space Weather*, *3*, S07B02, doi:10.1029/2005SW000151.

Ono, Y., M. Nosé, S. P. Christon, and A. T. Y. Lui (2009), The role of magnetic field fluctuations in nonadiabatic acceleration of ions during dipolarization, *Journal of Geophysical Research (Space Physics)*, *114*, A05209, doi: 10.1029/2008JA013918.

Rème, H., et al. (2001), First multispacecraft ion measurements in and near the Earth's magnetosphere with the identical Cluster ion spectrometry (CIS) experiment, *Annales Geophysicae*, *19*, 1303–1354.

Speiser, T. W. (1965), Particle Trajectories in Model Current Sheets, 1, Analytical Solutions, , *70*, 4219–4226, doi: 10.1029/JZ070i017p04219.

Tverskoy, B. A. (1972), Primary mechanism for the formation of the radiation belts of the earth, in *Physics of the Magnetosphere [in Russian]*, p. 278, Mir.

Welling, D. T., V. K. Jordanova, S. G. Zaharia, A. Glocer, and G. Toth (2011), The effects of dynamic ionospheric outflow on the ring current, *J. Geophys. Res.*, *116*, A00J19, doi:10.1029/2010JA015642.

Wilken, B., et al. (2001), First results from the RAPID imaging energetic particle spectrometer on board Cluster, *Annales Geophysicae*, *19*, 1355–1366.

Winglee, R. M., and E. Harnett (2011), Influence of heavy ionospheric ions on substorm onset, *Journal of Geophysical Research (Space Physics)*, *116*, A11212, doi:10.1029/2011JA016447.

Yau, A. W., B. A. Whalen, W. K. Peterson, and E. G. Shelley (1984), Distribution of upflowing ionospheric ions in the high-altitude polar cap and auroral ionosphere, , *89*, 5507–5522, doi:10.1029/JA089iA07p05507.

B Addresses of all participants

Prof. Maha Ashour-Abdalla
Institute of Geophysics and Planetary Physics, University of California,
603 Charles E. Young Drive, East, Los Angeles CA 90095, USA
Phone: +1 310 825-8881
Fax: +1 310 206-3051
Email: mabdalla@igpp.ucla.edu

Dr. Iannis Dandouras
Institut de Recherche en Astrophysique et Planétologie,
9, Avenue du Colonel Roche, 31028 Toulouse, France
Phone: +33 5 61 55 83 20
Fax: +33 5 61 55 67 01
E-mail: Iannis.Dandouras@cesr.fr

Dr. Dominique Delcourt
LPP, Ecole Polytechnique - CNRS,
4 avenue de Neptune, 94107 Saint Maur des Fossés France
Phone: +33 1 44 27 92 69
Fax: +33 1 48 89 44 33
E-mail: dominique.delcourt@lpp.polytechnique.fr

Dr. Elena Grigorenko
Space Research Institute, Russian Academy of Sciences,
Profsouiznaia 84/32 Moscow, GSP-7, 117997, Russia
Phone: +7 095 333 14 67
Fax: +7 095 333 51 78
Email: grig@romance.iki.rssi.ru

Prof. Lynn Kistler
University of New Hampshire,
8 College Rd., Morse Hall, Durham, NH, USA
Phone: +1 603 862 1399
Fax: +1 603 862 0311
Email: Lynn.Kistler@unh.edu

Dr. Elena Kronberg
Max Planck Institute for Solar System Research,
Max-Planck Str., 2, Katlenburg-Lindau, 37191, Germany
Phone: +49 5556 979481
Fax: +49 5556 979240
Email: kronberg@mps.mpg.de

Dr. Romain Maggiolo
Belgian Institute for Space Aeronomy,
Avenue Circulaire 3, 1180 Brussels, Belgium
Phone: +32 2 373 03 64
Fax: +32 2 374 84 23
Email: maggiolo@aeronomie.be

Dr. David Shklyar
Space Research Institute, Russian Academy of Sciences,
Profsouiznaia 84/32 Moscow, GSP-7, 117997, Russia
Phone: +7 095 333 45 34
Fax: +7 095 333 33 11
Email: david@iki.rssi.ru

Dr. Yuri Shprits

Institute of Geophysics and Planetary Physics, University of California,
405 Hilgard Ave / 7127 Math Sciences Bldg, Los Angeles CA 90095, USA
Phone: +1 310 825 1038
Fax: +1 310 206 5219
Email: yshprits@atmos.ucla.edu

Dr. Daniel Welling
Department of Atmospheric, Oceanic, and Space Sciences, Univ. of Michigan,
2455 Hayward St., Ann Arbor, MI 48109-2143, USA
Phone: +1 734-625-2717
Fax: +1 734-615-9723
Email: dwelling@umich.edu