Fall 2011 THEMIS/ARTEMIS SWG

Meeting Schedule

Westin Annapolis ~ 100 Westgate Circle, Annapolis, MD 21401 ~ 410-972-4300

Wednesday Sept. 14th
Morning Session: Programmatic and Science Sampler for HQ

8:30AM - Registration and badging (E. Masongsong)
9:00AM - Welcome/Logistics (D. G. Sibeck & E. Masongsong)
9:05AM - Mission status and accomplishments (Angelopoulos)
9:25AM - View from HQ (Hays and Goodrich)
9:55AM - Looking forward: RBSP and THEMIS (Ukhorskiy)
10:15AM - Status and news about the THEMIS GBOs (Donovan and Frey)
10:35AM - *Break*
10:50AM - The DREAM and ARTEMIS lunar plasma science connection (Farrell)
11:10AM - Mission Highlight: Lunar Precursor Effects Observed by ARTEMIS in the Solar Wind and Magnetosphere (Halekas)
11:30AM - Mission Highlight: First observations of a foreshock bubble: Implications for global magnetospheric dynamics and particle acceleration (Turner)
11:50AM - Mission Highlight: Direct evidence for a three-dimensional magnetic flux rope flanked by two active magnetic reconnection X-lines at the Earth's magnetopause (Øieroset- given by Phan)
12:10PM - *Lunch*

Afternoon Session: Dipolarization Fronts and ARTEMIS

1:20PM - Mission highlight: Possible Connection of Polar Cap Flows to Pre-Substorm Onset PBIs and Streamers and to Post-Onset Auroral Activity (Lyons- given by Nishimura)
1:40PM - Dipolarization Fronts and Onset of Reconnection in the Magnetotail (Sitnov)
2:00PM - Particle-in-cell simulation of Magnetotail dipolarization fronts and associated ion reflection (Wu)
2:20PM - THEMIS observations of mid-tail reconnection and dipolarization fronts (Runov)
2:40PM - *Break*
2:55PM - Pre-onset azimuthal pressure gradient and associated auroral intensifications related to dipolarization fronts (Xing)
3:15PM - Coupling of Dipolarization Front Flow Bursts to Substorm Expansion Phase Phenomena within the Magnetosphere and Ionosphere (Lyons- given by Xing)
3:35PM - Auroral activity and ion distribution associated with magnetotail earthward-propagating dipolarization fronts (Ge)
3:55PM - Ion distributions upstream of earthward propagating dipolarization fronts (Zhou)
4:15PM - Lunar surface charging: comparison of ARTEMIS data and particle-in-cell codes (Poppe)
4:35PM - On the size of magnetotail flux ropes at ~ 60 RE downtail (Kiehas)
4:55PM - A Statistical Survey of the Distant Magnetotail using THEMIS/ARTEMIS: Preliminary Results on Plasma Distribution and Transports (Stubbs)
5:15PM - Velocity and E-Field Variations of the Geomagnetic Field During the Passage of Interplanetary Shocks (Kaymaz)

Thursday Sept. 15th
Morning Session: Substorms and associated phenomena

9:00AM - Energy Source For Auroral Electrons From Two Proposed Substorm Onset Processes (Lui)
9:20AM - Super-Alfvénic propagation of reconnection energy: Kinetic PIC simulations and satellite observations (Shay)
9:40AM - Statistical Relation between Mid-latitude Positive Bays and Other Substorm Onset Signatures (Chu)
10:00AM - Auroral signature of ground Pi 2 pulsations (Nishimura)
10:20AM - *Break*
10:35AM - Alfvénic arcs observed by FAST and the THEMIS GBO all-sky cameras (Frey and Mende)
10:55AM - Comparison of electric field observations between THEMIS satellites and their ionospheric conjugate points (Liu)
11:15AM - The magnetospheric source of proton aurora: implications for mapping (Donovan and Spanswick)
11:50AM - *Lunch*

Afternoon Session: Programmatic

1:00PM - The Solid State Telescope (SST) instruments: An update on recent progress in calibration, characterization, and decontamination (Turner)
1:20PM - SPDF Tools and Activities Supporting THEMIS/ARTEMIS (McGuire)
1:40PM - Orbit Design Updates for Upcoming Seasons (S. Frey)
2:00PM - *Break, then transit to boat dock (carpool)*
3:00-5PM - Sailing! Prompt 3PM departure. http://www.schoonerwoodwind.com/directions.asp
Schooner Woodwind: 80 Compromise St., Annapolis MD, 410-263-7837
6:30PM - Banquet Dinner at Mike's Crab House (carpool)
3030 Riva Road, Riva, MD, 410 956-2784

Friday morning (Inner Magnetosphere and Dayside)

9:00AM - Whistler-mode chorus waves in the dayside outer magnetosphere: PENGUIn/AGO and THEMIS conjugate observations (Keika)
9:20AM - A search of ion cyclotron waves in the magnetotail at the lunar orbit (Chi)
9:40AM - Recent progress in field line resonance sounding of the plasmasphere by ground magnetometer networks (Chi)
10:00AM - Frequency Doubling in Compressional Pc5 pulsations: Meridional Motion of the Equatorial Line of Nodes in the Ballooning-Mirror Instability (Sibeck and Korotova)
10:20AM - *Break*
10:35AM - THEMIS Case Studies of Geo-effective Stream Interaction Regions (Mays)
10:55AM - THEMIS Observations and Simultaneous Auroral Imaging on the dayside (Mende)
11:15AM - 3D Magnetopause Modeling with Multi-Spacecraft Observations and Support Vector Machine (Wang)
11:35PM - Out-Of-Sample Run-On-Request Tool empirical geomagnetic field model TS07D (Stevens)
11:55PM - *Lunch* – Room is reserved till 5:00PM for ongoing discussions

WEDNESDAY

RBSP Mission: Understanding Particle Acceleration and Electrodynamics of the Inner Magnetosphere

A.Y. Ukhorskiy, B. Mauk, N. Fox, D.G. Sibeck

During past 50 years of space exploration and research our understating of radiation belts considerably evolved. It is now recognized that radiation belt fluxes exhibit highly dynamical nonlinear response to varying geomagnetic conditions with complex spatial and temporal properties. Some profound physical mysteries still remain. Their solution is critical for Space Weather applications at Earth as well as our understanding of fundamental mechanisms of high-energy particle acceleration and transport across the universe. Predictive understanding of dynamic variability of the belts requires a broad range of coordinated measurements of particles and fields that determine particle motions. NASA RBSP two-spacecraft mission in collaboration with other space missions, balloon and ground based observations will provide a complete set of measurements to address complex variability of the belts. We will discuss science goals and objectives of the RBSP mission and collaboration with the THEMIS mission to understand how global electrodynamics of the inner magnetosphere governs acceleration and variability of energetic particle populations in the belts.

Status and News about the THEMIS GBOs

Eric Donovan and Harald Frey

We will describe the status of the THEMIS GBOs, new developments about the funding situation, and new software tools that are now available for the community.

The DREAM and ARTEMIS lunar plasma science connection

W.M. Farrell, R.M. Killen, G.T. Delory, and the DREAM Lunar Science Institute

The objective of the DREAM institute is to further the understanding of the solar-lunar environmental coupling responsible for the neutral exosphere, ionosphere, and solar wind plasma perturbations observed at the Moon. Many of the ongoing DREAM studies dovetail nicely with the ARTEMIS mission, and these studies will be described. Examples include modeling of the trailing lunar plasma wake, the lunar response to CMEs /solar storms, exo-ion creation and pickup, and the examination of a lunar precursor region. Institute models are already being used in support some of ARTEMIS' activities, and we anticipate that this great connection will be enhanced as the mission progresses.

Lunar Precursor Effects Observed by ARTEMIS in the Solar Wind and Magnetosphere

Jasper Halekas

Abstract: The Moon to first order acts as a simple absorber of plasma, resulting in a downstream wake in flowing plasma, and charging of the surface in response to incident currents. However, recent data from several missions have shown that some effects of the Moon can be observed at large distances from its surface, at some times even in the upstream direction. We present observations of a variety of lunar precursor effects observed by the new two-probe ARTEMIS mission, which achieved lunar orbit insertion in June/July 2011. In the terrestrial magnetosphere, we observe magnetically reflected electrons (forming a loss cone distribution) and electrostatically accelerated secondary/photo electron beams that can travel very large distances from the lunar surface, producing a variety of waves in both the whistler and Langmuir range. In the solar wind, with a more significant ambient density and flow, upstream effects are more muted, but still present. Both ions and electrons can be reflected and/or produced at the dayside surface, feeding back into the upstream plasma environment and producing waves capable of affecting the ambient environment.

First observations of a foreshock bubble: Implications for global magnetospheric dynamics and particle acceleration

Drew L. Turner, Nick Omidi, David G. Sibeck, and Vassilis Angelopoulos

Earth's foreshock is a unique plasma region capable of generating several kinds of large-scale phenomena, each of which can impact the magnetosphere resulting in global effects. Recently, a new type of foreshock phenomena has been predicted: foreshock bubbles, which arelarge-scale disruptions of both the foreshock and incident solar wind plasmas that can result in global magnetospheric disturbances. Here, we present unprecedented, multi-point observations of foreshock bubbles at Earth using the THEMIS spacecraft and ground magnetometer network. We include detailed analysis of the

events' global effects on the magnetosphere and the energetic ions and electrons accelerated within the foreshock bubble. This particle acceleration occurs potentially by a combination of first and second order Fermi and shock drift acceleration processes. Foreshock bubbles should play a role in energetic particle acceleration at collisionless, quasi-parallel shocks throughout the Universe, and these THEMIS observations provide direct evidence of these events, which can be used to compare with and constrain models.

Direct evidence for a three-dimensional magnetic flux rope flanked by two active magnetic reconnection X-lines at the Earth's magnetopause

Marit Øieroset, Tai Phan, Jonathan Eastwood, Masaki Fujimoto,Bill Daughton, Mike Shay, Vassilis Angelopoulos, Forrest Mozer, Jim McFadden, Davin Larson, Karl-Heinz Glassmeier

We report the direct detection by three THEMIS spacecraft of a magnetic flux rope flanked by two active X-lines producing colliding bi-directional plasma jets near the center of the flux rope. The observed density depletion and open magnetic field topology inside the flux rope inferred from electron behavior reveal that the flux rope has important three dimensional effects that are significantly different from those of two-dimensional magnetic islands. Furthermore, fluxes of 1 - 4 keV super-thermal electrons observed in the flux rope core were higher than those in the converging reconnection jets implying local electron energization within the flux rope. The large flux rope, with its cross section diameter exceeding 200 ion skin depths, also contains ion skin depth scale substructures within its core.

Possible Connection of Polar Cap Flows to Pre-Substorm Onset PBIs and Streamers and to Post-Onset Auroral Activity

L. R. Lyons, Y. Nishimura, H.-J. Kim, E. Donovan, V. Angelopoulos, G. Sofko, M. Nicolls, C. Heinselman, J. M. Ruohoniemi, and N. Nishitani

Recent analysis of a short period of observations has led to the hypothesis that enhanced meso-scale flows from well within the region of along open polar cap field lines may cross the nightside polar cap boundary into the closed field line region and contribute to the triggering of equatorward (earthward) meso-scale flows across the ionospheric (equatorial) end of plasma sheet fields lines and lead to PBIs and streamers, including the streamers that have been postulated to bring new plasma equatorward (earthward) and lead to substorm onset. Meso-scale structure of flow within the polar cap, often studied near the dayside polar cap boundary, has not previously been generally recognized as significant within the nightside polar cap. Here we have taken advantage of new capabilities to measure polar cap convection by the Resolute Bay incoherent scatter radar and the Rankin Inlet PolarDARN radar, coordinated with THEMIS all-sky imager observations, to study flow measurements from well within the polar cap to near the polar cap boundary. We present evidence that flow structures moving from the polar cap towards the nightside polar cap boundary may be important for triggering the flows that lead to substorm onset streamers. The new observations also have given evidence that the flow structures come from deep within the polar cap, and have given unexpected evidence that a continuation of flow structures moving from the polar cap towards the nightside polar cap boundary after substorm onset may be important in controlling the poleward expansion and duration of post-onset auroral activity.

Dipolarization Fronts and Onset of Reconnection in the Magnetotail

M. I. Sitnov and M. Swisdak

Dipolarization fronts turned out to be in the focus of the magnetotail studies in the past few years. One of the key questions in the context of the THEMIS mission is the mechanism of their formation, whether it is related to magnetic reconnection or other plasma processes in the magnetotail. For example, recent 3D PIC simulations suggest that DFs do even not arise from reconnection, but can instead be formed as a result of the ballooning-interchange instability. We consider PIC simulations starting from new classes of 2D current sheet equilibria, including multiscale magnetotail current sheets, and show that DF formation can play an integral part in reconnection onset due to the tearing instability. During DF formation, current sheets behave as metastable systems where the transition from slow to fast phases is not caused by topological changes. Rather, the fast phase resembles the formation of bubble-blob pairs, which then promote the formation of new X-lines and electron diffusion regions. The fast phase shares properties with the ion tearing instability. It is also similar to the catapult instability, which was recently discussed by Machida et al. [2009] as a new scenario for substorms.

Particle-in-cell simulation of Magnetotail dipolarization fronts and associated ion reflection

Penny Wu

For the Earth's magnetotail, some statistical studies infer that the lobe density is highly variable, in the range 0.007-0.092/cc. Such inflow density variation modifies the reconnection diffusion region physical processes and reconnection rate drastically. We examine observable reconnection signatures in the downstream that are to be affected by this variation of the diffusion region physics. Using a 2.5-D particle-in-cell (PIC) code, we characterize the dipolarization front (DF) normal magnetic field, the DF propagation, the associated ion reflections, and the heating at various inflow densities. Our computational results re-affirm the current observational evidence of ion reflection [zhou et al., 2010]. Further, we predict a bipolar magnetic field straddling the neutral line and the fishbone instability inside the primary island. We identify the streaming of the reflected ions as the cause of the observed features.

THEMIS observations of mid-tail reconnection and dipolarization fronts

A. Runov, X.Z. Zhou, V. Angelopoulos

We examine multi-point observations of magnetotail dynamics during events when THEMIS probes located in the mid-tail plasma sheet detected signatures which are commonly attributed to magnetic reconnection in the magnetotail plasma sheet (tailward/earthward bulk flow with southward/northward magnetic field) while probes located in the near-Earth plasma sheet detected abrupt increase in the northward magnetic field component (dipolarization fronts). Addressed questions are i) what is the physical relation between mid-tail reconnection and dipolarization front formation, and ii) on which stage of reconnection the dipolarization fronts are formed.

Pre-onset azimuthal pressure gradient and associated auroral intensifications related to dipolarization fronts

X. Xing, L. R. Lyons, V. Angelopoulos, X. Zhou, E. Donovan, D. Larson, C. Carlson, and U. Auster

The plasma pressure spatial distribution and the magnetic field in force balance with it determine the distribution of the Field-Aligned Current (FAC) in the quasi-static near-Earth plasma sheet. The time evolution of the azimuthal plasma pressure gradient during undisturbed periods is of particular importance in leading to the evolution of FACs, which strongly affect the ionospheric current circulation and the aurora formation before dynamical processes strike, e.g., substorms. *Xing et al*. (2011) demonstrated by case study that the plasma sheet pressure gradient at ~11 R_E near the substorm onset meridian undergoes a substantial duskward enhancement shortly before the onset as identified from the auroral poleward expansion. The increased upward FAC driven by this pressure gradient enhancement leads to the thin onset arc intensification from which the poleward expansion initiates. The mechanism of the formation of such a transient duskward pressure gradient is still an open question. In the present study, we employ the multi-THEMIS spacecraft in azimuthal conjunction -at ~-11 R_E and examine the ion flux and distributions during the period of pressure gradient enhancement. Strong field-aligned ion flux enhancements covering the energy range from several KeV to above 25KeV were observed by the spacecraft identifying the higher pressure increase, while at the same time the ion distributions show substantial field-aligned, mushroom-like shift in velocity space. These resemble the ion acceleration ahead of earthward moving dipolarization fronts in a highly stretched magnetic field during the late growth phase. The local plasma develops strong transient parallel anisotropy due to the ion acceleration. On the other hand, the spacecraft observing the lower pressure increase found weaker or no ion flux enhancements and had nearly isotropic distributions. Due to these spatial differences, similar transient pressure gradient enhancements in the dawnward direction were also found for some events. These suggest that the transient azimuthal pressure gradient enhancement near the onset meridian could result from the azimuthal difference of the ion acceleration caused by the localized dipolarization fronts that reach the near-Earth plasma sheet at the onset meridian. The associated transient upward FAC enhancement, which leads to the thin onset arc intensification, would thus be related to the current pair generated in the plasma compression region ahead of the dipolarization front. Thus the earthward penetrating plasma flow channels could play a dominant role in leading to substorm onset.

Coupling of Dipolarization Front Flow Bursts to Substorm Expansion Phase Phenomena within the Magnetosphere and Ionosphere

L. R. Lyons, Y. Nishimura, T. Kikuchi, A. Runov, V. Angelopoulos, and E. Donovan
(Talk by X. Xing)

THEMIS spacecraft observations have shown narrow, plasma sheet flow channels with large, abrupt magnetic field dipolarizations that appear to move earthward as coherent structures. We find that these events, referred to as

dipolarization fronts, most often occur during the substorm expansion phase after onset and are likely related to auroral streamers. We also present evidence that the dipolarization front field and plasma perturbations make unexpectedly large contributions to substorm dipolarization. Thus, for the events considered, it may not be correct to think of a single substorm current wedge Instead, the substorm current wedge appears to have developed via a series of well-defined, narrow wedge-like structures, and without a smooth azimuthal expansion of these features. We have furthermore found that, for these events, the auroral zone magnetic field showed modest responses to the onsets, but more abrupt and larger responses to the post-onset dipolarization-front-related streamers, and that the initiation of mid-latitude positive bays occurred near the time of streamer formation, which can be well after onset. These results suggest that ground magnetic responses traditional viewed as signatures of substorm onset may at times misidentify onset times by up to 10's of minutes. Also, we do not see any fundamentally difference in responses to expansion phase flow channels that have been formally identified as dipolarization fronts and those that have not. It should be interesting in the future to determine the extent to which the above features are, and are not, general features of a substorm expansion phase.

Auroral activity and ion distribution associated with magnetotail earthward-propagating dipolarization fronts

Yasong S. Ge, Xuzhi Zhou, Jun Liang, Joachim Raeder, Eric Donovan, and Matthew L. Gilson

Abstract: The Earthward-propagating dipolarization fronts (DFs) are often found to be associated with magnetotail reconnection and Bursty Bulk Flows (BBFs) in the tail. Recently the THEMIS observations show a DF propagating over 10RE from the mid-tail region to the near-Earth tail region and THEMIS All-Sky Imager data shows a north-south auroral form and intensification of westward auroral zone currents. In this study, we examine the observations of several tail DFs from THEMIS and ground-based Meridian Scanning Photometers (MSP) of the NORSTAR network. We find that the observed Earthward-moving DFs are often seen to be associated with intensification of ionospheric proton aurora when the THEMIS spacecraft are conjugated with the scanning meridian of MSPs. The intensification of proton aurora associated with the DFs appears transient and sometimes they are detached from the background proton precipitation. It is also found that right before the DFs the ion distribution is anisotropic in the field-aligned direction and mostly Earthward, and the ion energy increases. These observations suggest that the plasma sheet protons can be reflected and energized by the Earthward-moving DFs as DFs propagate through the magnetotail. These energized protons are reflected back to the stretched magnetic field in front of DFs and can be scattered into the loss-cone to precipitate into the ionosphere. This population of ions can be the source of the intensification of proton aurora observed on the ground.

Ion distributions upstream of earthward propagating dipolarization fronts

Xuzhi Zhou, Yasong Ge, Vassilis Angelopoulos, Andrei Runov, Jun Liang, Xiaoyan Xing, and Qiugang Zong

We present case studies of THEMIS multi-point observations on ion distributions in the magnetotail plasma sheet at various locations upstream of earthward propagating dipolarization fronts. Gradual enhancements of earthward-moving ion fluxes have been observed in the central plasma sheet ~30 seconds before front arrivals, a characteristic signature well explained in previous studies as front-reflected ions coexisting with the ambient population in a confined region characterized by their gyroradii over background Bz field. In the plasma sheet boundary layer, observations have shown the appearances of earthward moving ions a few more minutes earlier than their appearances in the central plasma sheet, indicating a larger accessibility region of front-reflected ions. As the magnetic field lines are predominantly in the x direction in the plasma sheet boundary layer, the reflected ions could move along the field lines and eventually result in auroral activities in the ionosphere. Numerical simulations, as well as theoretical analysis of ion dynamics, have been carried out to interpret the observed patterns of ion distributions, and to improve our understandings of interactions between earthward propagating fronts and the ambient plasma in the near-Earth magnetotail.

Lunar surface charging: comparison of ARTEMIS data and particle-in-cell codes

A. Poppe, J. S. Halekas, G. T. Delory, W. M. Farrell

The dayside lunar surface charges in response to various ambient currents, including photo- and/or secondary emission and collection of solar wind or geomagnetic plasma. Standard charging theory would predict lunar surface potentials on the order of +5V in the solar wind, for example; however, recent modeling and analysis of Lunar Prospector data have shown that these potentials can occasionally be negative on the dayside due to the presence of non-monotonic potentials above the surface. These potentials reflect most of the incoming electron population while trapping a large fraction of the photoelectrons near the surface. Here we report on previous and current efforts at modeling the solar wind/geomagnetic plasma interaction with the dayside lunar surface using a 1- and 1&½-d particle-in-cell code, including the role that lunar crustal magnetic anomalies may have in modifying the surface plasma environment. In addition, the two ARTEMIS probes, now in lunar orbit, will provide a wealth of new data on the extent and variability of non-monotonic potentials above the lunar surface with which to compare to the PIC model.

On the size of magnetotail flux ropes at ~ 60 RE downtail

Stefan Kiehas

The ARTEMIS mission allows us to determine the size, evolution and structure of flux ropes and plasmoids by using dual spacecraft observations. On July 15th, 2011, the two ARTEMIS probes were locates at about 60 RE downtail with a separation in x,y,z (GSM) of about 7.5, 11.3 and 1.7 RE respectively. THB, located in the pre-midnight sector and closer to the current sheet than THC, observes four flux ropes during a one hour interval. THC, located in the post-midnight sector, catches only one of the four flux ropes, observed by THB. The other flux rope events lead to small disturbances in the magnetic field, to fainted to be identified as TCRs. The size of the flux ropes in x is between 8 and 15 RE, which is in agreement with previous investigations. However, the extension in y is significantly restricted, as opposed to previous studies. This indicates that also at 60 RE downtail the region where flux ropes appear is constrained and does not cover an extensive cross-tail area.

A Statistical Survey of the Distant Magnetotail using THEMIS/ARTEMIS: Preliminary Results on Plasma Distribution and Transport

Timothy J. Stubbs, Yongli Wang, David G. Sibeck, Jan Merka, and Vassilis Angelopoulos

The region of the Earth's magnetosphere tailward of ~30 R_E remains relatively unexplored. A better characterization of the processes taking place in the distant magnetotail is critical to a more complete understanding of the coupling between the solar wind and the Earth's magnetosphere. This survey will also provide a unique assessment of the magnetotail plasma encountered by the Moon, which will be valuable for understanding how the lunar environment is modified during these traversals. The THEMIS/ARTEMIS missions have returned sufficient data from this region in order to allow a large-scale statistical survey to be undertaken.

In this preliminary study, various plasma moments are organized by occurrence frequency and distance down the magnetotail. Further sorting is done to identify different regions of the magnetotail, such as the tail lobes and plasma sheet, and the physical processes taking place, such as reconnection. This is the first step in constructing a comprehensive large-scale picture of the energization, distribution, and transport of plasma in the distant magnetotail.

Velocity and E-Field variations of the Geomagnetic Field During the Passage of Interplanetary Shocks

Zerefşan Kaymaz, David G. Sibeck, Andrey Samsonov, and Vassilis Angelopoulos

The effects of the interplanetary shocks (IP) on the magnetosphere have been investigated using state-of-the-art THEMIS velocity and electric field measurements. Several studies indicate that the interaction of the magnetopause with the IP shocks transmitted through the magnetosheath launches a fast wave in the magnetosphere. MHD models predict that this wave then reflects from the plasmasphere boundary or ionosphere. Magnetic field and velocity measurements, particularly from THEMIS A, D, and E were studied during IP shock passages and the resulting signatures classified. As the quality of the measurements made by the instruments on THEMIS exceeds that from previous work on the IP-magnetosphere relationship, this study will add to the knowledge on the velocity variations of the magnetosphere directly inferred from these measurements. Case studies showing the velocity and E-field characteristics of the magnetospheric response will be presented. The data and signatures will be discussed within the framework of the predicted reflected wave.

THURSDAY

Energy Source For Auroral Electrons From Two Proposed Substorm Onset Processes

A.T.Y. Lui

There are two main processes in the tail that are proposed to link with electron precipitation for the initial brightening auroral arc at substorm onset. These are current disruption/dipolarization (CDD) and magnetic reconnection (MR). To provide further clues in differentiating these two processes, we examine the electron energy spectrum and the associated total field-aligned energy flux during six CDD events and compare them with five MR events. Data from AMPTE/CCE, Geotail, and THEMIS missions are used in this study. It is found that (1) the total field-aligned energy flux from CDD sites is generally high enough to account for the energy flux required to produce bright auroral arcs at substorm onsets, and (2) the total field-aligned electron energy flux from MR sites is generally a factor of one to two orders of magnitude lower than that from CDD sites. These results favor a direct link between the CDD sites and the substorm onset arcs but they do not rule out further acceleration of auroral electrons away from these sites by other energy sources (e.g., field-aligned potential drops and kinetic Alfvén waves).

Super-Alfvénic propagation of reconnection energy: Kinetic PIC simulations and satellite observations

Michael Shay

Although magnetic reconnection is known to play an important role in both magnetospheric substorms and solar flares, the peak propagation speed of energy away from the reconnection site is not well established. While bulk flows are limited to the Alfven speed, the quadrupolar Hall magnetic field is associated with a kinetic Alfvén wave (KAW) with a super- Alfvenic parallel propagation speed and substantial Poynting energy flux. The statistical properties of this poynting flux is consistent with a statistical study of magnetotail reconnection signatures. The Poynting flux associated with this kinetic Alfven wave is substantial, and rough estimates of its mapping to the ionosphere yield sufficient energy to create white light aurora. We extend this previous work using large scale reconnection simulations of comparable size to the near Earth magnetotail,
focussing on the modification of the KAW as it propagates towards Earth and the relative energy budget between Poynting flux and energetic electrons. Implications for our understanding of substorms will be discussed.

Statistical Relation between Mid-latitude Positive Bays and Other Substorm Onset Signatures

Xiangning Chu, Robert L McPherron, Tung-Shin Hsu, Jeniffer Kissinger

Magnetospheric substorm plays a key role in the coupling of the solar wind and the magnetosphere. A sudden intensification of aurora which moves poleward and westward is usually identified as the indicator of substorm onset. High-latitude negative bay and mid-latitude positive bay (MPB) usually accompany the auroral brightening. Furthermore, dipolarization in geosynchronous orbit and dispersionless injection are usually observed during a substorm. It is believed that these phenomena are highly correlated and that they are manifestations of the formation of the Substorm Current Wedge (SCW) at substorm onset.

A large statistical study of the correlation among these phenomena has not been previously reported. In this study, a database of substorm onsets is determined by AL indices, MPB observed by INTERMAGNET, auroral observation by IMAGE and All Sky Images (ASI) from the THEMIS ground network, geosynchronous dipolarization by GOES, dispersionless injection by LANL and tail dipolarization by THEMIS. Time-delay and occurrence frequency analysis between these different onset lists shows that these phenomena are not always correlated in a one-to-one manner. Approximately 65% of MPB onsets are found to be associated with AL onsets and the association rates are similar between MPB onsets and other substorm onset signatures. Further work is necessary to clarify why this is the case for different kinds of onsets. The solar wind driving condition and the response function of magnetosphere is also studied for different categories of events.

Auroral signature of ground Pi 2 pulsations

Toshi Nishimura, Larry Lyons, Takashi Kikuchi, Eric Donovan, Vassilis Angelopoulos, Peter Chi and Tsutomu Nagatsuma

Pi 2 pulsations have been known to occur associated with substorm auroral onset. Although several models have been proposed [Lester et al., 1989; Kepko et al., 2001; Takahashi et al., 2004], the driver of Pi 2s has remained controversial. By taking advantage of the THEMIS ASIs, which have high resolution and wide spatial coverage, the present study examines if the aurora shows any periodic disturbances in the Pi 2 frequency, and if so, what within the magnetosphere drives the Pi 2 oscillation. We find that PBIs and ensuring streamers form quasi-periodically soon after substorm onset and that the expansion-phase streamers occurred simultaneously with individual midlatitude Pi 2 pulses. When ground magnetometers were located near the streamers, the negative bay also oscillated synchronously with the streamers in anti-phase with midlatitude Pi 2. Furthermore, the latitudinal distribution of Pi 2 amplitudes from the McMac magnetometer chain data were found to follow well that from the current wedge model. The correlation between the ground Pi 2 and auroral streamers suggest that the driver of the ground Pi 2 is located in the plasma sheet as multiple flow bursts, which quasi-periodically changes the wedge current FACs leading to ground Pi 2 pulsations. Cases where dayside ground magnetometer data were available showed that dayside low latitude Pi 2s are detected without time lag from the nightside midlatitude Pi 2 and show equatorial enhancements. This suggests that the ionospheric potential electric fields associated with the FAC changes are quickly transmitted to the entire ionosphere and lead to the simultaneous occurrence of Pi 2 even on the dayside, where there is a substantial equatorial enhancement. These observations lead us to conclude that the substorm Pi 2 is driven directly by the plasma sheet disturbances rather than by the cavity mode resonance in the plasmasphere. This supports the model by Kepko et al. [2001] and suggests that quasi-periodic reconnection followed by localized flow bursts leads to the Pi 2.

Alfvénic arcs observed by FAST and the THEMIS GBO all-sky cameras

H.U. Frey and S.B. Mende

During the past northern winter seasons there were several occasions when the FAST spacecraft measured the particle signatures of Alfvenic arcs while traversing the fields of view of the THEMIS GBO all-sky cameras. There are three general classes of Alfvenic arcs. Alfvenic arcs can be found at the leading poleward edge of broad inverted-V arcs immediately after the expansion onset of substorms. They can also be found as single isolated arcs poleward of the main auroral oval arcs where they seem to be unrelated to substorm activity. But, as a third class, Alfvenic arcs can also be found at the equatorward edge of broader arcs. We will show examples of these three classes and discuss their signatures and potential implications for the generation of auroral arcs.

Comparison of electric field observations between THEMIS satellites and their ionospheric conjugate points

Guiping Liu, Scott England, Stephen Mende, Thomas Immel, Harald Frey, John Bonnell, Vassilis Angelopoulos

Hundreds of measurements of magnetospheric electric fields magnetically conjugate to operating ground radars have been made by the Electric Field Instrument (EFI) onboard the THEMIS satellites at 7-10 RE geocentric distance. In this study, these measurements are compared to the ionospheric electric fields at the northern conjugate point at Poker Flat (65°N, 147°W). For the comparison, the magnetic field measurements are subtracted for the $E = - V \times B$ component produced by the spacecraft motion. The corrected data have a magnitude of a few mV/m, providing a significant measurement of the electric field in the magnetosphere. The data are then compared to the simultaneous observations by the ground-based incoherent scatter radar at Poker Flat. The Tsyganenko magnetic field model is used to map the magnetic footprints from the THEMIS spacecraft positions to the ground. The data are selected for comparison to radar measurements when the satellite footpoints fall into the range of the radar measurements. Comparisons are made for both the electric field directions and magnitudes, and differences are found between the THEMIS observations in the magnetosphere and the radar data for the ionosphere.

The magnetospheric source of proton aurora: implications for mapping

Eric Donovan & Emma Spanswick

The bright proton aurora is understood be the projection of the inner Central Plasma Sheet (CPS) where there is sufficient particle energy to cause auroral luminosity but still strong pitch angle scattering (presumably due to field line curvature). This region is often interpreted as the transition region between dipolar and tail-like magnetic topologies. The location of auroral features relative to the peak in the proton aurora has been used, for example, to argue that the substorm onset arc exists on field lines that thread this transition region. Using an empirically derived relationship between FAST (ElectroStatic Analyzer) ESA data and ground-based proton auroral luminosity, we are able to convert THEMIS ESA measurements of ion flux near the loss cone to an equivalent proton auroral luminosity. We explore the consistency of these two methods for determining a satellite's location relative to the IB. We can also place these events in the context of a statistical picture of the late growth phase. We demonstrate that the peak in the proton aurora intensity maps to inside of 10 Re in the late growth phase, and that even under magnetically quiet conditions, the entire bright proton auroral distribution originates inside of 15 Re.

The Solid State Telescope (SST) instruments: An update on recent progress in calibration, characterization, and decontamination

Drew L. Turner, Patrick Cruce, Vassilis Angelopoulos, and Davin Larson

We will present recent progress with the SST dataset, including: intercalibration between anodes on individual spacecraft, intercalibration with the ESA instruments, and Geant4 simulations to characterize instrument performance and background response. The techniques for each of these tasks will be discussed, followed by examples and results. We will close with a preview of the variety of science questions that can be addressed when the newly calibrated and decontaminated dataset is available and how these data will benefit the upcoming RBSP mission.

SPDF Tools and Activities Supporting THEMIS/ARTEMIS

Bob McGuire and the SPDF Team at NASA Goddard

Even as the Space Physics Data Facility (SPDF) is starting planning and work to support the upcoming RBSP and MMS

missions, SPDF continues its support of THEMIS science and its science community. We will briefly update the status of THEMIS data and information now available through CDAWeb and SSCWeb, as well as extensions to the CDF standard that are now under development. We'll also discuss SPDF's role as a NASA Heliophysics active Final Archive and how we see our services expediting coordinated science among THEMIS, other existing missions and upcoming new missions.

Orbit Design Updates for Upcoming Seasons

Frey, S.

I want to present a quick overview of the upcoming dayside season for the inner THEMIS probes and outline plans for the tail season thereafter. For the ARTEMIS probes I will present the latest update of the lunar phase orbits with emphasis on regions of interest for FastSurvey data collection.

FRIDAY

Whistler-mode chorus waves in the dayside outer magnetosphere: PENGUIn/AGO and THEMIS conjugate observations

K. Keika, M. Spasojevic, W. Li, J. Bortnik, Y. Miyoshi, V. Angelopoulos, A.J. Gerrard

We perform a case study of whistler-mode chorus waves in the dayside outer (L>7) magnetosphere under quiet geomagnetic conditions. We use simultaneous conjugate observations made at 1230-1930 UT on 26 July 2008 by three THEMIS spacecraft and a ground-based VLF receiver at an automatic geophysical observatory (AGO) in Antarctica supported by the US Polar Experiment Network for Geospace Upper-atmosphere Investigations (PENGUIn) project.

VLF wave intensification was observed by THEMIS A, D, and E. Filter bank data show that all three THEMIS probes observed wave intensification in the 287-1240 Hz range around noon and 6-9 RE near the equatorial plane. Waveform data from THEMIS A show that the waves were intensified in a frequency range of 500-800 Hz (0.3-0.4 fce) with rising tone elements and circularly right-handed polarized. VLF signals at the AGO P2 station (AP2: MLAT = -76.6 deg.; MLT = UT-3.5h) were intensified in the frequency range of 500-1000 Hz around noon. We confirmed, from fluxgate magnetometer data, that AP2 was equatorward of the open-closed boundary. Solar wind dynamic pressure was constant and weak (~1 nPa); the Dst index was around -10 nT; and the AE index showed weak activity (<200 nT).

We examine the configuration of magnetic field lines in which the THEMIS spacecraft and the AGO stations reside during the wave intensification, and find that the intensification occurred when field lines have small gradient along a field line (dB/ds) in a wide range of magnetic latitude. We suggest that chorus wave growth in such compressed field lines is responsible for the observed continuous intensification of dayside chorus waves during quiet geomagnetic conditions. We discuss about two possible generation mechanisms: non-linear wave growth due to greater electron trapping and linear growth in a uniform medium for an extended length.

A search of ion cyclotron waves in the magnetotail at the lunar orbit

Peter J. Chi

Recently a small portion of the Apollo Lunar Surface Magnetometer (LSM) data have been restored, and in these data several events of narrow-banded waves at 0.1-0.2 Hz were found when the LSM was in the magnetotail. These narrow-banded waves are left-handed polarized and have frequencies close to the local proton cyclotron frequency, suggesting that they are ion cyclotron waves in nature. Here we present examples of the ion cyclotron waves observed by Apollo LSM, and we examine the wave observations by ARTEMIS when the two probes orbiting the Moon in the magnetotail.

Recent progress in field line resonance sounding of the plasmasphere by ground magnetometer networks

P. J. Chi

We report our latest progress in using the observations by ground magnetometer networks to monitor the plasmasphere. The observations include those collected by McMAC, Falcon, and THEMIS GBO/EPO stations. Together these stations can form over 100 station pairs for finding the field line resonance (FLR) frequencies through the gradient technique, and the FLR frequencies can in turn be used to infer the two-dimensional distribution of equatorial plasma mass density. We demonstrate the capability and results of our algorithm for automatic detection of FLR in ground magnetometer data, which can facilitate future near real-time monitoring of plasmaspheric density through ground magnetometer networks.

Frequency Doubling in Compressional Pc5 pulsations: Meridional Motion of the Equatorial Line of Nodes in the Ballooning-Mirror Instability

D.G Sibeck and G. I. Korotova

Quiet-time compressional Pc5 pulsations observed within the dawnside equatorial magnetosphere often exhibit frequency doubling, in which the northward component of the magnetic field oscillates at frequencies twice as great as those of the azimuthal or radial component. We use THEMIS-A ESA plasma velocity moments and gyrophase observations of suprathermal ions on November 7, 2007 to argue against proposed explanations for the frequency doubling that invoke either the radial or azimuthal sloshing of plasma and magnetic field gradients past the observing spacecraft, or the combined effects of non-adiabatic radial flux gradients and drift-bounce resonances, in favor of an explanation in terms of meridional oscillations in the equatorial line of nodes for antisymmetric field-line motion. The latter enables near-equatorial spacecraft to observe two magnetic field strength enhancements, one north and one south of the line of nodes, per wave cycle. Despite a small temperature anisotropy, the large plasma beta suffices to satisfy the criteria for the ballooning-mirror instability. In combination with antisymmetric electric fields, drift shell splitting on stretched magnetic field lines results in suprathermal ions streaming alternately parallel and antiparallel to the magnetic field.

THEMIS Case Studies of Geo-effective Stream Interaction Regions

M.L. Mays

Following a statistical study of stream interaction regions and CME events during solar minimum which result in storm and substorm activity, the THEMIS measured magnetospheric response for selected events is presented. In particular I will discuss the stream interaction region driven events of 14-17 February 2011 and 6-11 January 2011 which included a large pressure pulses and magnetopause crossings over THEMIS. For event selection, geomagnetic activity is characterized by indices derived from ground based magnetometers and a minimum Dst threshold of -30 nT is used. For each geoeffective event, we identified CMEs in the STEREO/SECCHI coronagraphs, and SIRs in the STEREO/SECCHI Heliospheric Imagers and associated lower coronal signatures in STEREO/EUVI and SDO/AIA. Subsequent CME and/or SIR signatures were identified in ACE, WIND, THEMIS, and other in-situ data when available. CME evolution in the lower corona and properties such as acceleration, speed and width were determined along with the in-situ plasma data for ICMEs. The propagation of these structures were tracked in the STEREO Heliospheric Imagers and subsequently in-situ. Geo-effectiveness, the strength and duration of geomagnetic activity, is compared with upstream solar wind conditions. In 2007 and 2008, SIRs produce most of the storms (~75% and ~78% respectively), however the strongest storms are produced by ICME and SIR interactions in 2007 and SIRs in 2008. The number of SIR driven storms drops to just below half (~46%) in 2009, and the remaining storms result from an ICME followed by an SIR (~39% and strongest storm), and ICMEs (~16\%). In 2010 the number ICME driven storms markedly increase (~50%) and produce 57% of the strongest storms, while SIR driven storms continue to decrease (36%). So far in 2011, and around half of the storms are SIR driven, but ~66% of the strongest storms are driven by ICMEs. Overall, the percentage of geo-effective SIRs (observed in-situ) from 2007-2009 was 36%, 30%, and 14%, respectively. ICMEs observed in-situ were geo-effective 60%, 33%, and 42% of the time.

THEMIS Observations and Simultaneous Auroral Imaging on the dayside.

S.B. Mende, S. Raghunathan, H.U. Frey.

During the Austral winters of 2007, 2008 and 2009 the five THEMIS satellites were in favorable position to observe the dayside boundaries of the magnetosphere while the conjugate aurora was imaged from Antarctica. Dual channel 630 and 427.8 nm imagers were operated at South Pole station and at other Antarctic sites of the US Polar Experiment Network for Geospace Upper-atmosphere Investigations (PENGUIn) network of Automatic Geophysical Observatories (AGO) provided the simultaneous data of the auroral response to changes in the solar wind during the Antarctic winters of these years. The THEMIS satellite positions were magnetically mapped to the auroral ionosphere to select the aurora that was most likely to be conjugate to the satellite. Using the mapped magnetic foot point of the satellite special keograms were produced which show the time-latitude behavior of the aurora at the longitude of the foot point. It is expected that the mapping is relatively accurate on the dayside because the magnetic field lines are relatively short. This procedure allowed the comparison of the aurora at the foot of the magnetic field line of the THEMIS satellites when the satellites crossed the magnetopause. Most times the satellites saw multiple crossings of rapidly moving magnetospheric boundaries that moved in response to either solar wind pressure pulses or spontaneous reconnection.

3D Magnetopause Modeling with Multi-Spacecraft Observations and Support Vector Machine

Yongli Wang, David G. Sibeck, Jan Merka, Scott A. Boardsen, Homa Karimabadi, and Tamara B. Sipes

As the inner boundary of the magnetosheath, the magnetopause is the location for energy, mass, and momentum transfer between the solar wind and the magnetosphere. The location of the magnetopause as well as its dependence on solar wind and geophysical conditions is critical for solar wind-magnetosphere interaction and global magnetosphere dynamics. Since the first theoretical solution of the shape and size of the magnetopause, many models have been proposed for magnetopause location. However, previous models used much fewer magnetopause crossings than what we have in this study, 15089, with much better coverage of magnetopause locations and control conditions. Previous studies also usually mandated analytical descriptions of magnetopause shape, which were then fit to subsets of crossings. In our study, advanced machine learning technique, Support Vector Regression Machine (SVRM), is used to explore this big database for the control of the magnetopause locations by Earth's dipole tilt, solar wind dynamic pressure, and IMF Bz without specifying the shape of the magnetopause. Localized model errors for each set of control conditions are also provided by this model for better evaluation of model results. Comparison of our model with some leading earlier models shows that the new model has smaller error, very well captures the subsolar magnetopause, high-latitude magnetopause, and cusps. Behavior of the new magnetopause model, including its asymmetry, magnetopause and cusp locations, is further studied under various typical solar wind conditions.

TS07D empirical geomagnetic field model: New science results and community service opportunities

Grant Stephens and Mikhail Sitnov

Conventional empirical geomagnetic field models can only offer climatological or synoptic descriptions of the magnetosphere depending on the general activity level and strongly restricted in their spatial resolution because of rigid custom-tailored modules describing major current systems. They are mainly used just as a utility tool providing a zero-approximation magnetic field for more science-oriented studies. Few exceptions known as event-oriented models [Kubyshkina et al., 1999; Ganushkina et al., 2004; Sergeev et al., 2011] have a fundamental problem of the mismatch between the large number of degrees of freedom of the model, necessary to describe storms and substorms, and the much less number of in-situ data points. The latter problem is resolved for storm scales in the new model TS07D (http://geomag_field.jhuapl.edu/model/), where a detailed description of the equatorial currents is combined with a sophisticated data-mining technique, which allows to use for the empirical reconstruction both in-situ and historical data. Thus the model provides a balance between earlier climatological and event-oriented approaches. It allows one to reconstruct the detailed 3D spatio-temporal structure of the combined ring-and-tail-current system, including field-aligned currents connecting the equatorial currents with the ionosphere. We demonstrate the model performance for several THEMIS-era events: March 8-11, 2008 (the strongest storm of the year driven by a CIR), April 5, 2010 (the "Galaxy 51" storm), August 4, 2010 (SME-driven storm) and January 6, 2011 (CIR-driven storm). We also introduce the new Run-On-Request tool, available at the model website and providing empirical reconstructions of any event in the period 1995-2011. Further development of the model down to substorm scales is also discussed.