# The Relationship Between Auroral Phenomenology and Magnetospheric Processes



**American Geophysical Union Chapman Conference**

Fairbanks, Alaska, USA

27 February – 4 March 2011

# AGU Chapman Conference on the Relationship Between Auroral Phenomenology and Magnetispheric Processes

Fairbanks, Alaska, USA
27 February – 4 March 2011

## Conveners

**Andreas Keiling,** UC Berkeley (USA)
**Eric Donovan,** University of Calgary (Canada)

## Program Committee

**Dirk Lummerzheim,** University of Alaska (USA)
**Dave Knudsen,** University of Calgary (Canada)
**Göran Marklund,** Royal Institute of Technology (Sweden)
**Vassilis Angelopoulos,** University of California Los Angeles (USA)
**Masafumi Hirahara,** University of Tokyo (Japan)
**Kirsti Kauristie,** Finnish Meteorological Institute (Finland)
**Fran Bagenal,** University of Colorado (USA)
**Robert Rankin,** University of Alberta (Canada)

# AGU Chapman Conference on the Relationship Between Auroral Phenomenology and Magnetispheric Processes

## Meeting At A Glance

### Sunday, 27 February 2011

| | |
|---|---|
| 1700h-1900h | Icebreaker and Registration |

### Monday, 28 February 2011

| | |
|---|---|
| 0915h-0930h | Welcome and Introductory Comments |
| 0930h-1115h | Auroral Phenomenology I |
| 1115h-1145h | Break |
| 1145h-1330h | Auroral Phenomenology II |
| 1330h-1430h | Lunch |
| 1430h-1530h | Auroral Phenomenology Poster Presentations |
| 1530h-1715h | Auroral Phenomenology III |
| 1715h-1730h | Break |
| 1730h-1800h | Discussion |
| 1800h-1900h | Social Hour (cash bar) |

### Tuesday, 1 March 2011

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|---|---|
| 0915h-0930h | Field Trip Information and News |
| 0930h-1115h | Relationship Between Aurora and Ionospheric Electrodynamics I |
| 1115h-1145h | Break |
| 1145h-1330h | Relationship Between Aurora and Ionospheric Electrodynamics II |
| 1330h-1430h | Lunch |
| 1600h-2300h | Field Trip to Chena Hot Springs |
| 1700h-2300h | Field Trip to Poker Flat Research Range |

### Wednesday, 2 March 2011

| | |
|---|---|
| 0915h-0930h | Conference Banquet Information and News |
| 0930h-1115h | Discrete Auroral Acceleration I |
| 1115h-1145h | Break |
| 1145h-1330h | Discrete Auroral Acceleration II |
| 1330h-1430h | Lunch |
| 1430h-1530h | Poster Presentations: Discrete Auroral Acceleration and Relationship Between Aurora and Ionospheric Electrodynamics |
| 1530h-1715h | Discrete Auroral Acceleration III |
| 1715h-1730h | Break |
| 1730h-1800h | Discussion |
| 1800h-1900h | Social Hour (cash bar) |
| 1900h-2100h | Conference Banquet |

### Thursday, 3 March 2011

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|---|---|
| 0915h-0930h | Field Trip Information and News |
| 0930h-1115h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients I |
| 1115h-1145h | Break |
| 1145h-1330h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients II |
| 1330h-1430h | Lunch |
| 1600h-2300h | Field Trip to Chena Hot Springs |
| 1700h-2300h | Field Trip to Poker Flat Research Range |

### Friday, 4 March 2011

| | |
|---|---|
| 0915h-0930h | Ice Festival Information and News |
| 0930h-1115h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients III |
| 1115h-1145h | Break |
| 1145h-1330h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients IV |
| 1330h-1430h | Lunch |
| 1430h-1530h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients Posters |
| 1530h-1700h | Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients V |
| 1700h-1715h | Break |
| 1715h-1745h | Discussion and Closing Remarks |
| 1800h-1900h | Social Hour (cash bar) |
| 1900h-2200h | Field Trip to Ice Sculpture Park |

# SCIENTIFIC PROGRAM

## SUNDAY, 27 FEBRUARY

1700h – 1830h **Conference Icebreaker**

1700h – 1900h **Conference Registration**

## MONDAY, 28 FEBRUARY

**Welcome and Introduction**
Gold Ballroom

**Auroral Phenomenology I**
Presiding: Dirk Lummerzheim
Gold Ballroom

0930h – 1010h **Syun-Ichi Akasofu** | The evolution of auroral morphological models (*Invited*)

1010h – 1030h **Nikolai Ostgaard** | Auroral asymmetries in the conjugate hemispheres during substorm onset and expansion phase (*Invited*)

1030h – 1050h **Harald U. Frey** | Aurora outside of the auroral oval (*Invited*)

1050h – 1110h **David J. Knudsen** | Auroral Arcs: How Much Do We Really Understand?

1110h – 1115h Additional Session Time

1115h – 1145h Break

**Auroral Phenomenology II**
Presiding: Dirk Lummerzheim
Gold Ballroom

1145h – 1205h **Joshua L. Semeter** | Coherence in auroral fine structure (*Invited*)

1205h – 1220h **Ryuho Kataoka** | Ground-based high-speed imaging observation of auroral microstructures

1220h – 1235h **Kristina Lynch** | Nightside observations of ray motion along an auroral PBI curtain: in situ and groundbased optics case study

1235h – 1250h **Robert G. Michell** | Dispersion Analysis of Flickering Aurora

1250h – 1310h **Marc Lessard** | Recent Advances in Pulsating Aurora (*Invited*)

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|---|---|
| 1310h – 1325h | **Anita Kullen** \| On the dynamics of nightside originating transpolar arcs |
| 1325h – 1330h | Additional Session Time |
| 1330h – 1430h | Lunch |

1430h – 1530h **Auroral Phenomenology Posters**
Gold Ballroom

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|---|---|
| M-1 | **Tetsuo Motoba** \| Varying IMF By effects on interhemispheric conjugate auroral features during a weak substorm |
| M-2 | **Fran Bagenal** \| Internal magnetic field model deduced from the satellite induced aurora observations |
| M-3 | **Fran Bagenal** \| Anticipating Juno |
| M-4 | **Takanori Nishiyama** \| The source region and its characteristic of pulsating aurora based on the Reimei observations |
| M-5 | **Ayumi Yaegashi** \| Spatiotemporal Variations and Generation Mechanisms of Flickering Aurora |
| M-6 | **Brent Sadler** \| Auroral Precipitation as a Driver of Neutral Upwelling in the Cusp |
| M-7 | **Meghan R. Mella** \| Analysis of plasma bulk properties from the Cascades-2 sounding rocket |
| M-8 | **Makenzie Lystrup** \| Jupiter's Infrared Aurora From 1995 to 2000 as Imaged by the NASA IRTF |
| M-9 | **James W. Labelle** \| Ground-Level Detection of Auroral Kilometric Radiation |
| M10 | **Sarah Jones** \| A Statistical Study of Large-scale Aspects of Pulsating Aurora Using the THEMIS All-sky Imager Array |
| M-11 | **Laureline Sangalli** \| Estimating the Peak Auroral Emission Altitude from All-sky Images |
| M-12 | **Nataly Ozak** \| Atmospheric Effects of Auroral Ion Precipitation at Jupiter |

**Auroral Phenomenology III**
Presiding: Fran Bagenal
Gold Ballroom

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|---|---|
| 1530h – 1545h | **Kaori Sakaguchi** \| Ion cyclotron waves and co-rotating isolated proton auroras |
| 1545h – 1600h | **James W. Labelle** \| MF-Bursts: Terrestrial Auroral Radio Emissions Related to Polar Substorms |
| 1600h – 1625h | **John T. Clarke** \| Hubble Observations of Aurora at Jupiter and Saturn (*Invited*) |

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|---|---|
| 1625h – 1650h | **Bertrand Bonfond** \| When the moons create aurora: the satellite footprints on giant planets (*Invited*) |
| 1650h – 1715h | **Dave A. Brain** \| Aurora in Martian Mini-Magnetospheres (*Invited*) |
| 1715h – 1730h | Break |
| 1730h – 1800h | Discussion |
| 1800h – 1900h | **Monday Afternoon Social Hour** |

## TUESDAY, 1 MARCH

### Relationship Between Aurora and Ionospheric Electrodynamics I

**Presiding: David J. Knudsen**
Gold Ballroom

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|---|---|
| 0915h – 0930h | Field Trip Information and News |
| 0930h – 0950h | **Larry R. Lyons** \| Relationships Between the Aurora and an Interplay of Large and Mesoscale Structure of Electrodynamical Magnetosphere-Ionosphere Coupling (*Invited*) |
| 0950h – 1010h | **Shasha Zou** \| Mutual Evolution of Aurora and Ionospheric Electrodynamic Features during Substorms (*Invited*) |
| 1010h – 1025h | **Jennifer Kissinger** \| Evidence of Harang Discontinuity in Steady Magnetospheric Convection |
| 1025h – 1040h | **Joseph R. Kan** \| Dipolarization onset initiated by intense Cowling electrojet current loop: Substantiated by a THEMIS substorm observed on March 1, 2008 |
| 1040h – 1055h | **Akimasa Yoshikawa** \| Synthesis formulation for conductivity evolution near the ionospheric E-region including current carrier transition and energetic electron precipitation effects at the finite field-aligned current region |
| 1055h – 1115h | **Octav Marghitu** \| Auroral Arc Electrodynamics: Review and Outlook (*Invited*) |
| 1115h – 1145h | Break |

### Relationship Between Aurora and Ionospheric Electrodynamics II

**Presiding: David J. Knudsen**
Gold Ballroom

| | |
|---|---|
| 1145h – 1205h | **Licia C. Ray** \| Auroral Signatures of Ionosphere-Magnetosphere Coupling at Jupiter and Saturn (*Invited*) |

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|---|---|
| 1205h – 1225h | **Tom Stallard** \| Clues on Ionospheric Electrodynamics from IR Aurora at Jupiter and Saturn (*Invited*) |
| 1225h – 1240h | **Stephen R. Kaeppler** \| Current Closure in the Ionosphere: Results from the ACES Sounding Rocket |
| 1240h – 1255h | **Akimasa Ieda** \| Field-aligned Currents During an Intense Substorm as Estimated from Global Auroral Images and Ground Magnetic Observations |
| 1255h – 1310h | **Dmytro Sydorenko** \| Simulation of Ionospheric Feedback Instability in the Ionospheric Alfven Resonator |
| 1310h – 1325h | **Bjorn Gustavsson** \| Multi-instrument observations of Black Aurora, modelling and results |
| 1325h – 1330h | Additional Session Time |
| 1330h – 1430h | Lunch |
| 1600h – 2300h | **Tuesday Afternoon Field Trip to Chena Hot Springs** |
| 1700h – 2300h | **Tuesday Afternoon Field Trip to Poker Flat Research Range** |

## WEDNESDAY, 2 MARCH

### Discrete Auroral Acceleration I

Presiding: Robert Rankin

Gold Ballroom

| | |
|---|---|
| 0915h – 0930h | Conference Banquet Information and News |
| 0930h – 0950h | **Betty S. Lanchester** \| Imaging of aurora to estimate the energy and flux of precipitation (*Invited*) |
| 0950h – 1010h | **Takeshi Sakanoi** \| Fine-scale black aurora and its generation process using Reimei image-particle data (*Invited*) |
| 1010h – 1030h | **Christopher C. Chaston** \| The Alfvénic Aurora in Fields, Particles and Images (*Invited*) |
| 1030h – 1045h | **Gerhard Haerendel** \| Five Types of Auroral Arcs and their Sources |
| 1045h – 1100h | **Fabrice Mottez** \| Quasi-static electric structures formed through Alfvén waves interaction |
| 1100h – 1115h | **Arnaud Masson** \| Cluster multi-point observations of density cavities in the Auroral Acceleration Region |
| 1115h – 1145h | Break |

## Discrete Auroral Acceleration II

**Presiding: Robert Rankin**
Gold Ballroom

1145h – 1205h **Tomas Karlsson** | Overview of the auroral acceleration region (*Invited*)

1205h – 1220h **Colin Forsyth** | Multi-spacecraft observations of auroral acceleration in upward and downward current regions by Cluster

1220h – 1235h **Clare Watt** | Conversion of Poynting Flux to Electron Energy Flux by Shear Alfvén Waves

1235h – 1255h **Laila Andersson** | The Search for Double Layers in Space Plasmas (*Invited*)

1255h – 1310h **Melvyn L. Goldstein** | The Origin of High-Energy Electrons in Reconnection Events in Earth's Magnetic Tail and Their Fate in the Inner Magnetosphere

1310h – 1325h **Raymond Pottelette** | Nonlinear structures driven by tail reconnection processes in the Alfvénic region

1325h – 1330h Additional Session Time

1330h – 1430h Lunch

## 1430h – 1530h Discrete Auroral Acceleration Posters

Gold Ballroom

W-1 **Matthieu Berthomier** | Cluster observations of the mid-altitude auroral cleft

W-2 **Yan Song** | Alfvenic Generation of Discrete Auroral Arcs

W-3 **Yoko Fukuda** | Event and statistical studies on the energy and pitch angle distribution properties of electrons in the Inverted-V region

W-4 **Vincent Genot** | Numerical simulations of wave/particle interaction in inhomogeneous auroral plasmas

## 1430h – 1530h Relationship Between Aurora and Ionospheric Electrodynamics Posters

Gold Ballroom

W-5 **Yukitoshi Nishimura** | Pre-onset time sequence of auroral substorms

W-6 **Shasha Zou** | Multi-instrument observations of a substorm onset: its location and pre-onset sequence

W-7 **Allison N. Jaynes** | Observations of Neutral Upwelling in the Cusp Region: High-Altitude Atomic Oxygen Signatures Observed by the SCIFER2 Sounding Rocket

W-8 **Philip A. Fernandes** | Preliminary Measurements and Results from RENU (Rocket Experiment for Neutral Upwelling): Measurement of Soft Precipitation Flux as a Mechanism for Neutral Upwelling in the Dayside Cusp

W-9 **Lisa Wirth** | The Geophysical Institute Magnetometer Array: Making Real-Time Geophysical Measurements Available for Operational Space Weather Needs

W-10 **Kirsti Kauristie** | A statistical study of Traveling Ionospheric Disturbances based on EISCAT Svalbard Radar data

W-11 **Hanna Dahlgren** | On the energy and flux of thin North-South aligned auroral arcs

## Discrete Auroral Acceleration III

**Presiding: Andreas Keiling**
Gold Ballroom

1530h – 1545h **Peter A. Damiano** | Current fragmentation and energy dispersion in global scale Alfven waves

1545h – 1600h **Robert L. Mutel** | The Connection between Discrete Auroral Arcs and AKR: Evidence from Polar and Cluster Observations in the Acceleration Region

1600h – 1620h **Thomas E. Cravens** | Auroral Ion Precipitation and Acceleration at the Outer Planets (*Invited*)

1620h – 1640h **Robert E. Ergun** | Parallel Electric Fields in Jupiter's Aurora (*Invited*)

1640h – 1655h **Peter A. Delamere** | Satellite-induced electron acceleration and related auroras

1655h – 1710h **Yasir I. Soobiah** | A search for auroral-type ion beams in the Martian topside ionosphere

1710h – 1715h Additional Session Time

1715h – 1730h Break

1730h – 1800h Discussion

## 1800h – 1900h Wednesday Afternoon Social Hour

## 1900h – 2100h Conference Banquet

# THURSDAY, 3 MARCH

| | |
|---|---|
| | **Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients I**<br>**Presiding: Eric Donovan**<br>Gold Ballroom |
| 0915h – 0930h | Field Trip Information and News |
| 0930h – 0950h | **Michael G. Henderson** \| Observing the Magnetospheric Plasmas Associated with Different Types of Aurora (*Invited*) |
| 0950h – 1005h | **Robert J. Strangeway** \| The Relationship Between Magnetospheric Processes and Auroral Field-Aligned Current Morphology |
| 1005h – 1025h | **Christopher M. Cully** \| Kinetic Structure of the Tail Current Sheet (*Invited*) |
| 1025h – 1040h | **Joachim Birn** \| Auroral Arcs and Thin Current Sheets in the Geomagnetic Tail |
| 1040h – 1100h | **Natsuo Sato** \| Dynamic tracing geomagnetic conjugate points using synchronous auroras (*Invited*) |
| 1100h – 1115h | **Ingrid Sandahl** \| Deducing spatial properties of auroral primary particle distributions from ground-based optical imaging |
| 1115h – 1145h | Break |
| | **Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients II**<br>**Presiding: Eric Donovan**<br>Gold Ballroom |
| 1145h – 1205h | **Michael G. Henderson** \| Auroral Substorm Onsets, Pseudobreakups and Auroral Precursor Activity (*Invited*) |
| 1205h – 1220h | **Vadim Uritsky** \| Turbulent signatures of bursty bulk flows in mutispectral aurora |
| 1220h – 1240h | **Eric Donovan** \| Motion of Auroral Features and Plasma Sheet Flow (*Invited*) |
| 1240h – 1255h | **T. Pitkänen** \| EISCAT-Cluster observations of quiet-time near-Earth magnetotail fast flows and their signatures in the ionosphere |
| 1255h – 1310h | **Akira Morioka** \| Two-step evolution of auroral acceleration and substorm onset |
| 1310h – 1325h | **Stephen Mende** \| Substorm Triggering and high latitude pre-cursors |
| 1325h – 1330h | Additional Session Time |
| 1330h – 1430h | Lunch |

1600h – 2300h **Thursday Afternoon Field Trip to Chena Hot Springs**

1700h – 2300h **Thursday Afternoon Field Trip to Poker Flat Research Range**

## FRIDAY, 4 MARCH

### Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients III

Presiding: Fran Bagenal
Gold Ballroom

0915h – 0930h Ice Festival Information and News

0930h – 0950h **Emma J. Bunce** | Aurora and Magnetospheric Dynamics at the Giant Planets (*Invited*)

0950h – 1010h **Barry H. Mauk** | Auroral Current Systems at the Giant Planets (*Invited*)

1010h – 1025h **Marissa F. Vogt** | An Improved Mapping of Jupiter's Auroral Features to Magnetospheric Sources

1025h – 1040h **Peter A. Delamere** | Solar wind interaction with the giant magnetospheres

1040h – 1055h **Donald A. Gurnett** | Aurora, Electron Beams, Auroral Hiss, and Parallel Electric Fields Associated With Saturn's Moon Enceladus

1055h – 1110h **William S. Kurth** | Cassini Observations in and near the Source of Saturn Kilometric Radiation

1110h – 1115h Additonal Session Time

1115h – 1145h Break

### Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients IV

Presiding: Kirsti Kauristie
Gold Ballroom

1145h – 1205h **Marina V. Kubyshkina** | Problems of mapping from magnetosphere to ionosphere during substorms (*Invited*)

1205h – 1220h **Joachim Raeder** | OpenGGCM Simulation of a Substorm: Axial Tail Instability and Ballooning Mode Preceding Substorm Onset

1220h – 1235h **Yasong S. Ge** | BBFs, Dipolarization Fronts and their Auroal effects in the Global MHD simulation of February 27, 2009 Substorm

1235h – 1250h **Yasutaka Hiraki** | Characteristics of auroral arcs formed by the feedback instability with extended MHD effects

1250h – 1305h **Matthew L. Gilson** | Simulation of the longitudinal splitting of the nightside proton aurora during a substorm seen by the IMAGE spacecraft

1305h – 1320h **Michael J. Wiltberger** | Using satistical Methods to calibrate auroral models in global scale magnetosphere-ionosphere simulations

1320h – 1330h Additional Session Time

1330h – 1430h Lunch

1430h – 1530h **Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients Posters**
Gold Ballroom

F-1 **Baptiste Cecconi** | Jovian radio emissions modeling and their future investigation with EJSM

F-2 **Baptiste Cecconi** | Saturn kilometric auroral radiation polarization and beaming properties

F-3 **Daniel W. Swift** | Fast Earthward Flows, Alfven Waves and Auroral Acceleration

F-4 **Laurent Lamy** | Properties of Saturn kilometric radiation measured from its source region

F-5 **Xuzhi Zhou** | On the earthward precursor flows in advance of dipolarization fronts

F-6 **Joachim Raeder** | Global MHD Modeling of Pre-Onset PBI Events

F-7 **Osuke Saka** | Activation of auroras at the poleward edge by bifurcated fast plasma flows

F-8 **Maha Ashour-Abdalla** | Analysis of Electrostatic Solitary Waves Observed by Cluster in Auroral Current Regions

F-9 **I. Sandahl** | Equatorial signatures of an auroral bilge and a transpolar arc at 19 MLT observed by Cluster

F-10 **Xiaoyan Xing** | Azimuthal Pressure Gradient in the Near-Earth Plasma Sheet and Associated Auroral Development Soon Before Substorm Onset

F-11 **Aoi Nakamizo** | Energy conversion process in the near-earth plasma sheet during substorms deduced from data analysis and MHD simulation

F-12 **Satoko Saita** | Displacement of geomagnetic conjugate points due to substorm-related changes in the near-Earth magnetotail field structure

F-13 **Tsugunobu Nagai** | Linkage of magnetic reconnection in the magnetotail to substorm onset on the ground

F-14 **Feifei Jiang** | The relative spatial location of the inner edge of the electron plasma sheet to the possible magnetospheric source region of the equatorward pre-existing auroral arc

F-15 **Larry Kepko** | Linking space-borne and ground-based observations observed around substorm onset to magnetospheric processes

F-16 **Kathryn A. McWilliams** | Localized Dayside Proton-Induced Auroral Emissions in the Cusp and Polar Cap

F-17 **Robert J. Redmon** | A global view of O+ upward flows and outflow rates between DMSP and POLAR

F-18 **Jeff Grant** | Relating the equatorward boundary of the diffuse redline aurora to its magnetospheric counterpart

F-19 **Sungeun Lee** | Magnetosphere – ionosphere coupling processes associated with auroral electrons using the THEMIS electron data

F-20 **John K. Hargreaves** | Dynamic behaviour of patches of auroral radio absorption observed by imaging riometer and incoherent-scatter radar

F-21 **Jörg-Micha Jahn** | Auroral Proton Precipitation "Viewed" Differently: Quantifying Ion Precipitation Using ENA Emissions

F-22 **Vytenis M. Vasyliunas** | Dynamical Origin of Ionospheric and Birkeland Currents Associated with the Aurora

F-23 **Ahmed R. Kirmani** | Relationship between Interplanetary Magnetic Field and AE Index

F-24 **Viacheslav Pilipenko** | Dispersion relationship for the ballooning mode and instability criteria

F-25 **Xiaoyan Zhou** | Discrete Shock-Aurora in Dawn/Dusk: The Best Manifestation of Magnetic Shearing?

F-26 **Antonius Otto** | Entropy Constraints and Current Sheet Thinning During the Substorm Growth Phase

F-27 **Herbert Gunell** | Vlasov simulations of magnetic field-aligned electric fields

F-28 **Kyoung-Joo Hwang** | Particle energization and wave-particle interactions associated with substorm dipolarization fronts

F-29 **Chung-Sang Ng** | Electrostatic Structures in Space Plasmas: Studies of Two-dimensional Magnetic Bernstein-Greene-Kruskal Modes

F-30 **Teiji Uozumi** | AKR modulation and Global Pi 2 oscillation: Jan. 24, 1997 event

F-31 **Jun Liang** | THEMIS survey of electron cyclotron harmonic waves and their association with diffuse auroras

F-32 **Stephen E. Milan** | Auroral and Ionospheric Evolution During Substorms and Ramifications for the Earth's Magnetotail

F-33 **Yoshizumi Miyoshi** | Fine structures of precipitating electrons associated with pulsating aurora: Reimei observations

### Relationship Between Aurora and Magnetospheric Dynamics, Fields, and Gradients V

Presiding: Kirsti Kauristie
Gold Ballroom

| | |
|---|---|
| 1530h – 1550h | **Robert Rankin** \| Pc5 Field Line Resonances: Theory and Observations (*Invited*) |
| 1550h – 1605h | **Eric Donovan** \| Proton Aurora: Magnetospheric Source Region |
| 1605h – 1620h | **Marilia Samara** \| Ground-based Imager Observations of Fast Auroral Pulsations Conjugate to THEMIS Electric Field Measurements |
| 1620h – 1635h | **Wen Li** \| The Origin of the Pulsating Aurora: Modulating Whistler-Mode Chorus Waves |
| 1635h – 1650h | **Jeffrey M. Holmes** \| Relative shock-induced proton and electron auroral propagation: combined ground- and space-based optical measurements |
| 1650h – 1700h | Additional Session Time |
| 1700h – 1715h | Break |
| 1715h – 1745h | Discussion and Closing Remarks |
| 1800h – 1900h | **Friday Afternoon Social Hour** |
| 1900h – 2200h | **Ice Festival** |

# ABSTRACTS

listed by name of presenter

## Akasofu, Syun-Ichi

### The evolution of auroral morphological models (*Invited*)

Akasofu, Syun-Ichi[1]

1. International Arctic Research Center, Fairbanks, AK, USA

Global morphological studies of the aurora became possible after the IGY all-sky camera operation in 1957-58. The first morphological model of auroral substorms was established by Akasofu (1964). Since then, there have been many attempts to establish more complete models (cf. Feldstein and Starkov, 1967; Elphinstone et al., 1996). Meanwhile, the emphasis on auroral morphology and theoretical studies shifted to studies on substorm onset. However, because of the great complexity of auroral displays, auroral morphology is still very incomplete. Many crucial auroral features in understanding auroral substorms are pointed out in establishing a new auroral morphology.

## Andersson, Laila

### The Search for Double Layers in Space Plasmas (*Invited*)

Andersson, Laila[1]

1. LASP/CU, Boulder, CO, USA

In the late 1920s Langmuir postulated that charge separation near a plasma interface could lead to steady-state parallel electric fields. In the late 1950s scientists created a theory about parallel electric fields describing what are now known as double layers. This was followed by their verification in laboratory experiments. Sounding rocket observations in the 1960s suggested the existence of parallel electric fields in space plasmas, and satellites in the auroral region observed weak double layers in the 1970s. However, these weak double layers could not explain the large electrostatic potentials that were implied by observations of accelerated particle populations. For some time, strong double layers eluded direct observation and many alternative theories were developed in the 1980s and 1990s to account for the large potentials implied by the observations. But in early 2000s the first direct unequivocal observations were made of strong double layers in the auroral acceleration region. Following upon their detection in the aurora, direct observations of double layers have now been made in many other locations where two plasma populations interact. The presenter will give a personal view of the search for double layer in space plasmas and where we stand today.

## Ashour-Abdalla, Maha

### Analysis of Electrostatic Solitary Waves Observed by Cluster in Auroral Current Regions

Ashour-Abdalla, Maha[1]; Umeda, Taka[3]; Pickett, Jolene[4]; Goldstein, Melvyn L.[2]; Fazakerley, Andrew[5]; Masson, Arnaud[7]; Georgescu, Edita[6]

1. Institute of Geophysics and Planetary Physics, University of California at Los Angeles, Los Angeles, CA, USA
2. Code 673, NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. Solar-Terrestrial Environment Laboratory, Nagoya University, Aichi, Japan
4. Department of Physics and Astronomy, The University of Iowa, Iowa City, IA, USA
5. Mullard Space Science Laboratory, University College London, Holmbury St. Mary, United Kingdom
6. Max Planck Institute for Solar System Research, Max Planck Institute, Kattlenberg-Lindau, Germany
7. Science Operations Department, European Space Agency, Noordwijk, Netherlands

The four Cluster spacecraft have been transiting Earth's auroral acceleration region approximately every 2.3 days since 2008. The Wideband Data (WBD) plasma wave receiver mounted on all four spacecraft obtains high time resolution waveforms in several different frequency bands that span the range from 100 Hz to 577 kHz. We present WBD data obtained simultaneously on more than one Cluster spacecraft in and near the auroral downward current region in the two bands 100 Hz to 9.5 kHz and 700 Hz to 77 kHz. These frequency bands are well suited for observing electron scale Electrostatic Solitary Waves (ESWs). We examine and analyze the ESWs for similarities on different spacecraft, and investigate the conclusion based on FAST satellite data that ESWs are observed only in conjunction with upgoing field-aligned ionosphere electrons that are intense and accelerated (10 eV–10 keV). We also analyze the very short time duration ESWs (~20–30 microseconds) observed in the upward current region by the Cluster spacecraft. Such short time duration ESWs have not been previously reported in this region. We will present theoretical analyses and simulation studies of electrostatic solitary waves.

## Bagenal, Fran

### Internal magnetic field model deduced from the satellite induced aurora observations

Hess, Sebastien[1]; Bagenal, Fran[1]; Bonfond, Bertrand[2]; Grodent, Denis[2]; Zarka, Philippe[3]

1. LASP, Boulder, CO, USA
2. LPAP, Université de Liège, Liège, Belgium
3. LESIA, Observatoire de Paris, Meudon, France

The internal magnetic field of Jupiter has been modeled from the magnetic field measurements of several spacecraft. Nevertheless, the Jovian Magnetic field has large non-dipolar components compared to the Saturn and Earth fields, which are difficult to determine from the spacecraft measurements. One way to determine them comes from the observation of the UV footprints of Jovian satellites. The positions of the satellites and of their footprints are both known, and a good magnetic field model must reproduce this mapping. This has been partially done with previous models, but the mapping became insufficient for a precise study of the Jovian magnetosphere. We present here a model, derived from the satellite footprint observations, which gives a more accurate mapping of the magnetic field lines and is still consistent with the spacecraft measurements. Some consequences for the Jovian magnetosphere physics are also presented.

## Bagenal, Fran

### Anticipating Juno

Bagenal, Fran[1]

1. LASP/APS, University of Colorado, Boulder, CO, USA

The Juno spacecraft arrives at Jupiter in October 2016, entering a polar orbit with a periapsis of ~1.1 Jupiter radii. Over 33 orbits, Juno will offer unprecedented coverage of Jupiter's high-latitude auroral regions. In anticipation of Juno, we have followed the spacecraft trajectory through an empirical magnetic field model (Khurana and Schwarzl 2005), tracing the intersected field lines to the planet. This mapping provides the surface field strength, the location of the foot of the magnetic flux tube at the planet, and the expected loss cone observed at the spacecraft. This tool provides insight and planning support for the upcoming Juno mission. We show that the Juno trajectory crosses many auroral flux tubes by comparing the location of the foot of the intersected flux tube with the location of the statistical main aurora.

## Berthomier, Matthieu

### Cluster observations of the mid-altitude auroral cleft

Berthomier, Matthieu[1]

1. LPP, Saint-Maur, France

Mid-altitude auroral cleft crossings by the Cluster-II spacecraft are presented. The auroral cleft is the low- and mid-altitude region of the dayside Earth magnetosphere that is magnetically connected to the Low-Latitude Boundary Layer (LLBL) which forms in the vicinity of the magnetopause during periods of strong penetration of solar wind plasma into the magnetosphere. In the equatorward part of the cleft, we carrefully study the "electron-only" region that is unaccessible to magnetosheath ions due to the combined effect of their longer time-of-flight from the injection site and of the poleward motion of this site. We show that electron distribution functions are much more structured and anisotropic in the cleft than in the adjacent polar cusp where solar wind plasma diffuses into the magnetosphere along open magnetic field lines at higher latitudes. We relate these particle observations to the properties of the turbulence that is simulaneously detected in the auroral cleft. It is found that in the 1-10Hz frequency range, strong electrostatic and electromagnetic fluctuations are observed in the "electron-only" LLBL. A detailed analysis of the measured fluctuations leads us to the identification of small-scale (ion Larmor radius scale) kinetic Alfven waves that are associated with the intense field-aligned current that is carried by upgoing electron beams. We suggest that this current could be the free energy source of the waves. The analysis of oxygen ions distribution functions shows that simutaneous transverse ion heating takes place at the time of the strong kinetic Alfven wave activity. It is a good indication that these waves could be responsible for local ion heating due to a stochastic interaction at ion Larmor radius scale. Since the mid-altitude "electron-only" LLBL/cleft is a prefered locus for transverse ion heating, our case study points out the importance of using multi-instrument and high-time resolution data in order to understand the physical processes at work in these highly structured regions above the aurora.

## Birn, Joachim

### Auroral Arcs and Thin Current Sheets in the Geomagnetic Tail

Birn, Joachim[1]; Schindler, Karl[3]; Hesse, Michael[2]

1. ISR-1, Los Alamos Nat. Lab., Los Alamos, NM, USA
2. NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. Ruhr-University, Bochum, Germany

Quasi-static models of auroral arcs are associated with U-shaped or S-shaped electric potential. For sufficiently small scales potential differences across magnetic field lines should be associated with electron flow shear and Hall current layers in the near tail or dipole/tail transition region. We discuss features of thin current sheet formation and structure on the basis of particle-in-cell simulations and Vlasov equilibrium theory.

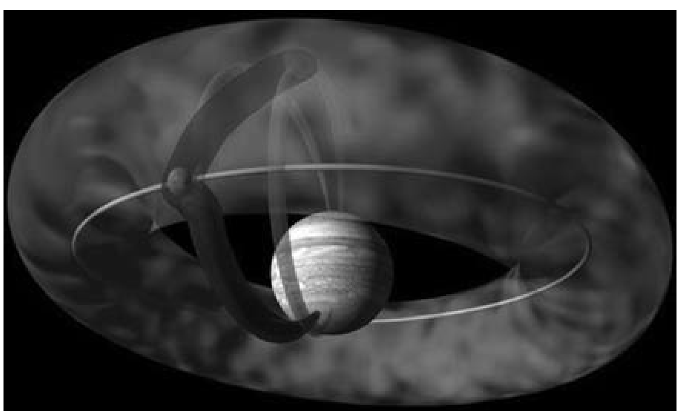
## Bonfond, Bertrand

### When the moons create aurora: the satellite footprints on giant planets (*Invited*)

Bonfond, Bertrand[1, 2]

1. LPAP, Université de Liège, Liège, Belgium
2. IGPP, University of California, Los Angeles, Los Angeles, CA, USA

Aurora on giant planets present many differences with the terrestrial aurora and the satellite footprints are among the most striking examples. Created by the interaction between the moons and the magnetospheric plasma, these auroral features are observed as spots or curtains located close to the field lines connecting the satellites to the planet. On Jupiter, the footprints of Io, Europa, and Ganymede have been discovered from ground observations in the infrared domain, Hubble Space Telescope observations in the ultraviolet domain, and Galileo spacecraft images in the visible domain. On Saturn, recent observations from the Cassini spacecraft tentatively identified the UV footprint of Enceladus. First we will briefly review the mechanisms driving these electro-magnetic interactions and their related observational evidences. Then we will discuss the characteristics of these various footprints, focusing on the better-studied cases of the Io and Ganymede footprints. We will see that the analysis of the footprint morphology, location, spatial extent, and brightness provides extremely valuable information both on the planetary magnetic field topology and on the processes at play in the interaction. And these processes are not so different from those creating some components of the Earth aurora.



Schematic of the electromagnetic interaction between Io and its plasma torus around Jupiter.

## Brain, Dave A.

### Aurora in Martian Mini-Magnetospheres (*Invited*)

Brain, Dave A.[1]

1. UC Berkeley Space Sciences Lab, Berkeley, CA, USA

It is somewhat surprising that aurora were detected at Mars only recently, given the large number of spacecraft to visit Mars relative to other planets. But Mars is capable of holding its secrets well, and the true nature of the Martian plasma interaction was only revealed in 1997, when the lack of a global dynamo was confirmed and the presence of strong crustal magnetic fields was detected. A few years later, in 2004, the appropriately instrumented Mars Express spacecraft made a happenstance observation of bright UV emission on the night side of the planet coming not from above the northern or southern polar cap, but from a small 'cusp' of crustal magnetic field. Since this initial observation an ever-expanding picture of Martian aurora is being assembled, from charged particle energization and transport into the collisional atmosphere to auroral emission to consequences for ionospheric structure and dynamics at Mars. In this presentation I will review the spacecraft observations of auroral processes active at Mars, including observations of UV auroral emission, observations of auroral-like precipitating electron distributions, and observations of 'inverted-V' ion and electron observations. I will also review the results of several theoretical and simulation studies related to Martian aurora. I will close by discussing the possible generation mechanisms for Martian aurora, and the consequences of these observations for studies of the Martian upper atmosphere, Martian climate evolution, and auroral processes elsewhere in the solar system.

## Bunce, Emma J.

### Aurora and Magnetospheric Dynamics at the Giant Planets (*Invited*)

Bunce, Emma J.[1]

1. Physics and Astronomy, University of Leicester, Leicester, United Kingdom

The rapidly-rotating magnetospheres of Jupiter and Saturn generate spectacular auroral emissions in their upper atmospheres, at a variety of observed wavelengths. The basic physical mechanisms producing the main emissions may be understood through studies and/or theoretical consideration of the plasma flows and field-aligned current systems present, which are typically generated through large-scale coupling processes. The generation mechanisms at Jupiter and Saturn appear to be quite different: Jupiter's main oval relates to large-scale currents associated with breakdown of plasma corotation in the middle magnetosphere, whilst Saturn's main emissions are driven by flow shears in the outer magnetosphere associated with the solar wind interaction. The scope for modulating the auroral emissions via magnetospheric dynamics at these two planets, therefore, is quite varied. Suggested and observed possibilities are associated with internally driven rotational affects (for example) the "Vasyliunas" process and related dynamics (Jupiter and Saturn), SKR phase affects and the rotating partial ring current (Saturn), competing with externally driven solar wind processes such as IMF-related or "cusp" emissions (Jupiter and Saturn), polar auroral filaments (Jupiter), Kelvin-Helmholtz instabilities (Jupiter and Saturn), and compression-induced auroral "storms" (Saturn). This talk will review the latest spacecraft and telescope observations and related modelling work.

## Cecconi, Baptiste

### Jovian radio emissions modeling and their future investigation with EJSM

Cecconi, Baptiste[1]; Hess, Sébastien[2]; Zarka, Philippe[1]

1. LESIA, Observatoire de Paris, Meudon Cedex, France
2. LASP, University of Colorado, Boulder, CO, USA

Dynamic spectra of planetary radio emissions depend on physical and geometrical conditions: emission process; energy of emitting electrons; angle between the source magnetic field and the wave direction, which varies with frequency; location of the observer... Their modeling is an intrinsically 3-dimensional problem for which a code has been developed: SERPE / ExPRES (Simulateur d'Emissions Radio Planétaires et Exoplanétaires / Exoplanetary and Planetary Radio Emissions Simulator). This tool has been successfully applied to the modeling of arc-shaped radio emissions generated by the Io-Jupiter electro-dynamic interaction, as well as of Saturn's Kilometric Radiation dynamic spectra. It allowed us to determine the energy of the emitting electrons, to identify the important of the oblique mode in the rarefied auroral plasmas of Jupiter and Saturn and to clarify the link between the Io-Jupiter radio emissions and of the UV spot at the magnetic footprint of Io. In light of these results, we will briefly review the characteristics of radio emissions related to Jupiter's aurorae and to satellite-Jupiter interactions. The EJSM mission is a unique opportunity to study the Jovian magnetosphere (from the close environment of Galilean satellites and their coupling with the Jovian magnetic field, to the auroral regions of Jupiter). It should carry the first goniopolarimetric radio receiver in Jovian orbit. We will illustrate with Cassini results the scientific enhancement of radio astronomy science brought by such capabilities that will not be available to any other mission around Jupiter. We will show how our present knowledge of Jupiter's decameter radio emissions may allow us to optimize the scheduling of low-frequency radar observations. Finally, we will discuss the unique opportunities that would be offered by multi-spacecraft magnetospheric observations in the Jovian system.

## Cecconi, Baptiste

### Saturn kilometric auroral radiation polarization and beaming properties

Cecconi, Baptiste[1]; Fischer, Georg[2]; Lamy, Laurent[1]; Zarka, Philippe[1]; Hess, Sébastien[3]; Ye, Sheng-Yi[4]; Taubenschuss, Ulrich[4]; Macher, Wolfgang[2]; Kurth, William S.[4]; Gurnett, Donald A.[4]

1. LESIA, Observatoire de Paris, Meudon Cedex, France
2. Space Research Institute, Austrian Academy of Sciences, Graz, Austria
3. LASP, University of Colorado, Boulder, CO, USA
4. University of Iowa, Iowa City, IA, USA

The high inclination orbits of the Cassini spacecraft from autumn 2006 until winter 2008 allowed the Cassini/RPWS (Radio and Plasma Wave Science) instrument to observe Saturn Kilometric Radiation (SKR) from latitudes up to 75° for the first time. This has revealed a surprising new property of SKR: Above ~30° in observational latitude a significant amount of SKR is strongly elliptically polarized, in marked contrast to previous observations from low latitudes, which showed only circular polarization. There are transitional latitudes where the elliptical polarization occurs in "patches" in the time frequency spectrograms next to regions of still completely circularly polarized SKR. From ~45°–60° in northern latitude it is found that most of the SKR is elliptically polarized throughout its entire frequency range with an average degree of ~0.7 in linear polarization. We also observe that the polarization of SKR goes back to fully circular at very high latitudes (>70°). We demonstrate the ellipticity of SKR by using the concept of "apparent polarization" in case of 2-antenna measurements, but also show 3-antenna measurements from which the polarization can be unambiguously determined. The beaming properties of the SKR sources are also investigated. We show that the simple conical shape of the CMI source beaming does not apply at Saturn. Possible reasons for the variation of SKR polarization and that of the SKR sources beaming with observer's location will be discussed. We also compare these inferred properties with that of terrestrial and jovian auroral radio emissions.

## Chaston, Christopher C.

### The Alfvénic Aurora in Fields, Particles and Images (*Invited*)

Chaston, Christopher C.[1]; Team, Fast[2]; Team, Reimei[3]

1. University of California, Berkeley, CA, USA
2. Various, UCB, UCLA, UCo, UNH, UM, GSFC, Various, CA, USA
3. Various, University of Nagoya, University of Tokyo, ISAS, Tohoku University, Various, Japan

Of the three processes which lead to the formation of aurora (pitch angle scattering, quasi-static field-aligned current closure and Alfvénic acceleration) Alfvénic acceleration, while predicted long ago is the most recently identified and is perhaps the most enigmatic. In the past decade or so in-situ measurements from a number of polar orbiting spacecraft have established particle acceleration in Alfvén waves as a significant contributor to auroral energy deposition and driver of energetic ion outflows from ionosphere. In this presentation we provide a review of the characteristics of the Alfvénic aurora in fields and particle observations and show recent observations from the Reimei spacecraft which have allowed its forms to be unambiguously identified from imager observations. We discuss unresolved issues in our understanding of the acceleration process in these waves and speculate on the wave sources. We also consider the relationship between the Alfvénic aurora and the quasi-static or inverted-V aurora associated with nearly time invariant field-aligned currents. Finally we consider the importance of Alfvénic acceleration processes in magnetosphere-ionosphere coupling and how it plays a role in geomagnetic storms and substorms.

## Clarke, John T.

### Hubble Observations of Aurora at Jupiter and Saturn (*Invited*)

Clarke, John T.[1]

1. Center for Space Physics, Boston University, Boston, MA, USA

This presentation will give an overview of the auroral emissions seen at Jupiter and Saturn, their characteristics, and the general level of understanding of the physics behind the emissions and controlling electrodynamic processes. Topics include the observed distribution and variations in auroral emissions, the different auroral emission regions on Jupiter, our understanding of the locations in the magnetospheres controlling the auroral emissions, and our understanding of the auroral physics for the different regions and emissions. Relevance to the large scale structure of the magnetospheres and interaction with the solar wind will also be discussed.

http://www.bu.edu/csp/PASS/aurora/index.html

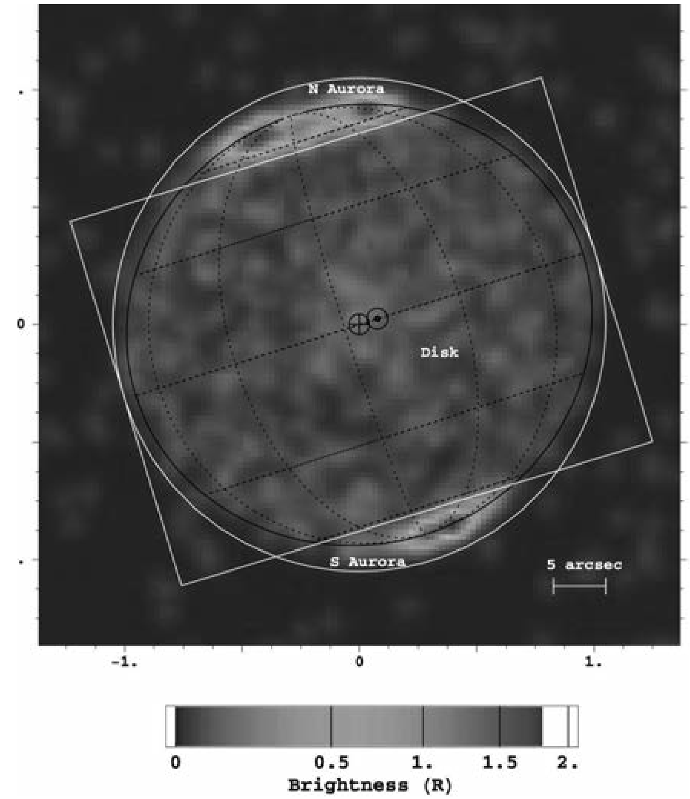
## Cravens, Thomas E.

### Auroral Ion Precipitation and Acceleration at the Outer Planets (*Invited*)

Cravens, Thomas E.[1]; Ozak, Nataly[1]; Hui, Yawei[2]; Schultz, Dave R.[2]; Kharchenko, Vasili[3]

1. Physics and Astronomy, Univ. of Kansas, Lawrence, KS, USA
2. Oak Ridge National Lab, Oak Ridge, TN, USA
3. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

Jupiter's aurora is known to be a powerful source of radio, infrared, visible, ultraviolet, and x-ray emission. An ultraviolet aurora has also been observed at Saturn. The UV aurora at Jupiter has been demonstrated to be produced by energetic electron precipitation associated with co-rotation lag in the middle magnetosphere. Jovian x-ray emissions with a total power of about 1 GW were observed by the Einstein Observatory, the Roentgen satellite (ROSAT), Chandra X-ray Observatory (CXO), and XMM-Newton Observatory. Most of the x-ray power is in soft x-rays from the polar caps but some harder x-ray emission from the main auroral oval was also observed by XMM Newton and is probably due to electron bremsstrahlung emission. Two possible mechanisms have been suggested for the soft x-ray emission: (1) cusp entry and precipitation of solar wind heavy ions and (2) acceleration and subsequent precipitation of ions from the outer magnetosphere. Recent theoretical models of ion precipitation and observations of spectra containing lines from high charge-state oxygen, and possibly sulfur, ions support the second mechanism. Ion acceleration by field-aligned potentials of about 10 MV is required for the x-ray production. Large downward parallel currents linking the polar cap to the magnetopause region are associated with this ion precipitation. This paper will review theoretical and observational aspects of ion aurora at the outer planets and the implications for magnetosphere-ionosphere coupling.




Chandra X-Ray Image of Jupiter (Elsner et al., 2005, JGR)

## Cully, Christopher M.

### Kinetic Structure of the Tail Current Sheet (*Invited*)

Cully, Christopher M.[1]

1. Swedish Inst. of Space Physics, Uppsala, Sweden

Far above us, magnetic field lines connect the aurora with the tail current sheet. With scale sizes frequently comparable to the ion gyroradius, any realistic description of this environment must be formulated kinetically. After reviewing several of the available kinetic current sheet models, I will discuss a technique for testing these models by fitting Cluster data to them. The resulting time-stationary reconstructions are self-consistent, with kinetic ions and fluid-like electrons. The reconstructions show 3 different typical cases. The least common are thin sheets supported by anisotropic electron currents. Somewhat more common are thin, sometimes bifurcated, sheets driven by electron Hall currents. Most commonly, the current is carried by diamagnetic ion currents, with small embedded structures due to variations in the electron temperature. Based on THEMIS and Cluster events, it appears that these embedded electron structures are the distant extensions of stable auroral arcs.

## Dahlgren, Hanna

### On the energy and flux of thin North-South aligned auroral arcs

Dahlgren, Hanna[1, 2]; Gustavsson, Björn[3]; Lanchester, Betty S.[3]; Ivchenko, Nickolay[1]; Brändström, Urban[4]; Whiter, Daniel K.[3]; Sergienko, Tima[4]; Sandahl, Ingrid[4]; Marklund, Göran[1]

1. Royal institute of Technology, Stockholm, Sweden
2. Boston University, Boston, MA, USA
3. University of Southampton, Southampton, United Kingdom
4. Swedish Institute of Space Physics, Kiruna, Sweden

Two north-south aligned, discrete auroral arc filaments have been analyzed using multi-station, multi-monochromatic optical observations from small and medium field-of-view imagers (the ASK and ALIS instruments) and the EISCAT radar. The energy and flux of the precipitating electrons, volume emission rates and local electric fields in the ionosphere have been determined at high temporal and spatial resolution. A new time-dependent inversion model is used to derive energy spectra from EISCAT electron density profiles. The characteristic energy and flux are also derived independently from ASK emissions combined with ion-chemistry modeling, and a good agreement is found. Here we present a robust method to obtain detailed 2-D maps of the energy and flux of small scale aurora. The two thin arcs are found to be associated with increased electron flux, and are at the boundaries between regions with precipitation of different characteristic energies. The lowest energies are found on the western, leading edges of the arcs. The large ionospheric electric fields found from tristatic radar measurements are evidence of strong currents associated with the region close to the optical arcs.

## Damiano, Peter A.

### Current fragmentation and energy dispersion in global scale Alfven waves

Damiano, Peter A.[1]; Johnson, Jay[1]

1. Princeton Plasma Physics Laboratory, Princeton, NJ, USA

Some of the most intense electron precipitation and largest ion outflows are found in regions of intense, Alfvenic waves. Recent analysis of auroral turbulence suggests that large scale waves couple energy to smaller scale lengths on the order of the electron inertial, ion acoustic or ion gyroradius scale lengths. A cascade of energy from global to kinetic scales is additionally evident in hybrid MHD-kinetic electron simulations of geomagnetic Field Line Resonances (also applicable to global scale waves on open field lines). In addition to the fragmentation of the upward current region associated with the energy cascade in these simulations, there is a significant dispersion of wave energy across magnetic field lines. This dispersion appears to coincide with the depletion of accessible current carriers within the original flux tube and the resulting acceleration of electrons along these adjacent field lines occurs within the confines of dispersive scale channels as well. In this presentation, we will highlight the characteristics of the simulated energy cascade, but will focus on the dispersion of wave energy across magnetic field lines and investigate how it changes with electron temperature, flux tube width and driving field amplitude. The attributes of the electron acceleration within the original flux tube (characterized by the formation of ring distributions in velocity space) and the fragmented current channels will additionally be contrasted and compared with electron signatures evident in observations.

## Delamere, Peter A.

### Satellite-induced electron acceleration and related auroras

Hess, Sebastien[1]; Delamere, Peter A.[1]; Dols, Vincent[1]

1. LASP, Boulder, CO, USA

Satellite-induced auroral emissions are known since decades, in particular those associated with the interaction of Io with the Jovian ionosphere. These emissions range from low frequency radio to UV. Flyby of Io allowed to better understand the power generation close to the satellite, and showed the existence of electron beams accelerated at high latitude. I will present a study of the power transfer between the local interaction at Io and the electron accelerated close to Jupiter. It shows that Alfvén acceleration explains the brightness of the Io related auroras observed in the UV and radio, as well as the electrons beams observed near Io. Moreover the study is extended to the Europa and Enceladus cases, with similar results.

## Delamere, Peter A.

### Solar wind interaction with the giant magnetospheres

Delamere, Peter A.[1]; Bagenal, Fran[1]

1. University of Colorado, Boulder, CO, USA

Jupiter's and Saturn's immense magnetospheres differ considerably from Earth's. These magnetospheres are generated in part by a strong planetary dynamo and by rapid rotation (~10 hour period). However, key differences lie in the internal sources of plasma (100s kg/s) provided by Io and Enceladus. Centrifugal stresses acting on the corotating, low-beta plasma in the inner magnetosphere leads to radial transport of plasma via a centrifugally-driven flux tube interchange instability. Instead of cooling on adiabatic expansion, the plasma is observed to be hotter at larger radial distances. In the outer magnetosphere the systems are governed by high-beta, centrifugally-confined plasma sheets. Observations and theories of the dynamics of Jupiter's and Saturn's magnetosphere will be discussed. In particular, we will focus on studies involving "viscous" processes (e.g. Kelvin-Helmholtz instability) at the magnetopause boundary that facilitate the transport of mass, momentum, and energy from the solar wind to the magnetosphere. Implications for polar auroral emissions will be discussed.

## Donovan, Eric

### Motion of Auroral Features and Plasma Sheet Flow (*Invited*)

Spanswick, Emma[1]; Donovan, Eric[1]; Kepko, Larry[2]; Rae, Kyle[1]

1. Department of Physics and Astronomy, University of Calgary, Calgary, AB, Canada
2. Space Weather Laboratory, NASA/Goddard Space Flight Center, Greenbelt, MD, USA

The dynamics of the aurora is often interpreted as a projection of large scale dynamics occurring in the Central Plasma Sheet (CPS). In this talk, we will explore the relationship between CPS and auroral dynamics using sequences of images from the THEMIS white light and NORSTAR multi-spectral imagers. By applying a robust technique for inferring the motion of features in a sequence of images we present statistics of the bulk "optical flow" seen in the THEMIS white light and NORSTAR multispectral cameras as a function of latitude and MLT. Motion inferred from the optical data shows evidence of both the large scale convection and also transient structured flows. We will present case studies of transient flows that occurred during a twenty day period in March-April 2009, when the NORSTAR imagers operated in a high resolution mode capturing the red-line aurora at a six second cadence (synchronized with the THEMIS ASI array). We will discuss the connection between the motion of specific types of auroral features and specific CPS transients including fast flows, as well as a superposed epoch analysis of auroral motions during the substorm growth phase.

## Donovan, Eric

### Proton Aurora: Magnetospheric Source Region

Donovan, Eric[1]; Spanswick, Emma[1]; McFadden, James[2]; Lui, Anthony[3]; Jackel, Brian[1]; Angelopoulos, Vassilis[4]

1. Physics and Astronomy, University of Calgary, Calgary, AB, Canada
2. Space Sciences Laboratory, University of California, Berkeley, CA, USA
3. Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA
4. Institute for Geophysics and Planetary Physics, University of California, Los Angeles, CA, USA

The arc that brightens at substorm onset is typically slightly poleward of the peak in the proton aurora. The location of proton aurora is thought to be a projection of the inner Central Plasma Sheet (CPS) where there is sufficient particle energy to cause proton auroral luminosity but still strong enough pitch angle scattering. This is the basis of the argument that the auroral brightening is driven by processes occurring in the transition region between the highly stretched magnetotail and the less stretched inner magnetosphere. However, this argument is qualitative and does ont allow one to assess, for example, whether the onset arc maps to the inner edge of the thin current sheet or to greater distances. This ambiguity is important as it limits the usefuleness of auroral observations in resolving key questions related to onset. As well, resolving this ambiguity will allow us to better relate the generation of auroral arcs to the physics at work in the magnetotail. In this paper, we explore the magnetospheric source region of the proton aurora using the results of two statistical studies, one of precipitating ions measured in the topside ionosphere by the FAST (ElectroStatic Analyzer) ESA instrument, and the other of THEMIS ESA ion observations in the night-side CPS. Using the FAST ESA observations and proton auroral brightnesses observed from ground-based photometers, we have derived a empirical relationship between integrated downward energy flux just above the ionosphere and the resulting proton auroral brightness. Since the precipitating ions are understood to be pitch angle scattered into the loss cone in the vicinity of the neutral sheet, it should also be possible to relate fluxes observed in the loss cone measured in the CPS to those measured in the topside ionosphere. Given our empirical relationship between the fluxes in the topside ionosphere and the proton auroral brightness, we take fluxes measured in the CPS and infer what the corresponding proton auroral intensity would be at the magnetic footprint of the satellite location. In other words, we are able to convert in situ measurements of ion flux in the vicinity of the neutral sheet to an equivalent proton auroral brightness at the magnetic footpoint of the location where the measurement was made. We find the not surprising result that the peak in the proton aurora intensity maps to inside of 10 Re, and that even under magnetically quiet conditions, the entire bright proton auroral distribution originates inside of 15 Re.

## Ergun, Robert E.

### Parallel Electric Fields in Jupiter's Aurora (*Invited*)

Ergun, Robert E.[1]

1. University of Colorado, Boulder, CO, USA

Jupiter displays several types of auroral processes that include, from lowest to highest latitudes, satellite-driven aurora (spots), a corotation-driven aurora (the main oval), and highly variable auroral activity in the polar regions connected to the outer magnetosphere, possibly influenced by the solar wind. We examine the generation and the impact parallel electric fields in the Io trail aurora and in the main auroral oval. In the Io-driven aurora, infrared and ultraviolet images have established that auroral emissions not only have a bright spot, but an emission trail that extends in longitude from Io's magnetic footprint. Electron acceleration that produces the bright spot is believed to be dominated by Alfvén waves whereas we show that the trail or wake aurora results from quasi-static parallel electric fields associated with large-scale, field-aligned currents between the Io torus and Jupiter's ionosphere. These currents ultimately transfer angular momentum from Jupiter to the Io torus. The same processes, current-driven quasi-static parallel electric fields play an important role in Jupiter's main auroral oval. We find that three physical processes dramatically alter the magnetospheric-ionospheric coupling. (1) The parallel potentials in the main oval are roughly two orders of magnitude higher than those in the Io wake causing significant de-coupling and nonlinear feedback between the ionosphere and the magnetosphere. (2) The precipitating electrons strongly alter the ionospheric conductivity that alter the magnetospheric-ionospheric coupling. (3) The low density region at ~ 2 RJ from Jupiter's center can significantly limit the field-aligned current, essentially acting as a "high-latitude current choke".

## Fernandes, Philip A.

### Preliminary Measurements and Results from RENU (Rocket Experiment for Neutral Upwelling): Measurement of Soft Precipitation Flux as a Mechanism for Neutral Upwelling in the Dayside Cusp

Fernandes, Philip A.[1]; Lynch, Kristina[1]; Lessard, Marc[2]

1. Department of Physics & Astronomy, Dartmouth College, Hanover, NH, USA
2. Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH, USA

RENU (Rocket Experiment for Neutral Upwelling) is a sounding rocket mission that will transit the cusp region during a neutral upwelling event. Recent satellite observations show evidence for atmospheric upwelling in the ionospheric cusp region. These thermospheric density peaks are most prominent in the dayside cusp, typically last several hours, and exhibit a one-to-one correspondence with fine-scale field aligned currents. The proposed mechanism of Joule heating does not appear to be adequate to describe the small-scale structures, and does not explain their lack of correlation with geomagnetic activity. A sounding rocket mission in conjunction with ground-based radar measurements will provide a case-study to further investigate the mechanism driving neutral upwelling. The RENU launch window is 28 Nov. 2010 – 12 Dec. 2010. We expect to present preliminary data and results. Dartmouth will be providing top-hat particle detectors for measurements of ion and electron quantities crucial to satisfying the science goals. These measurements include ion temperatures, which will provide an initial assessment of the upwelling process, and precipitating electron energy input, which both theory and observations suggest may contribute to neutral upwelling.

## Forsyth, Colin

### Multi-spacecraft observations of auroral acceleration in upward and downward current regions by Cluster

Forsyth, Colin[1]; Walsh, Andrew[1]; Fazakerley, Andrew[1]; Watt, Clare[2]; Garza, Kristian[1]; Owen, Christopher[1]; Constantinescu, Dragos[3]; Dandouras, Iannis[4, 5]; Fornacon, Karl-Heinz[3]; Lucek, Elizabeth[6]; Marklund, Goran[7]; Sadeghi, Seyed S.[7]

1. Mullard Space Science Laboratory, UCL, Dorking, United Kingdom
2. University of Alberta, Edmonton, AB, Canada
3. Technische Universität Braunschweig, Braunschweig, Germany
4. Centre d'Etude Spatiale des Rayonnements, Université de Toulouse, Toulouse, France
5. Centre National de la Recherche Scientifique, Toulouse, France
6. Blackett Laboratory, Imperial College, London, United Kingdom
7. The Royal Institute of Technology, Stockholm, Sweden

On the 14th December 2009, Cluster passed through an auroral acceleration region (AAR) at an altitude of 4400-5900 km. Cluster 4 passed through the AAR at 4450 km, 2.5 minutes prior to Cluster 1 and Cluster 3. Cluster 2 remained in the polar cap throughout the interval. The spacecraft observed various signatures of the AAR: low energy ion conics, inverted-V electron distributions, field-aligned currents and narrow beams of heavy ions. During their crossing, Cluster 1 and Cluster 3 were magnetically conjugate, separate by 1500 km, facilitating the determination of the average parallel electric field between the spacecraft from the particle acceleration. The passage of three closely separated spacecraft through this region at different times enables us to examine the spatial and temporal evolution of the electric field structures within the region. The AAR was separated into one region of downward current and two regions of upward current. The electric potential structures in this region persisted for at least 5 minutes. In the upward current regions, the electrons were accelerated through a potential drop of up to 500 V, whilst ionospheric ions were accelerated by ~1 keV, indicating parallel electric fields an order of magnitude smaller than the observed perpendicular electric field. We present the results of a multi-spacecraft study into this period.

## Frey, Harald U.

### Aurora outside of the auroral oval (*Invited*)

Frey, Harald U.[1]

1. Space Sciences Laboratory, Berkeley, CA, USA

Aurora generally occurs within continuous ovals around the two magnetic poles as mostly east-west aligned discrete arcs or an unstructured diffuse glow. It is the result of upper atmospheric excitation by precipitating energetic electrons and protons that were accelerated by electrostatic fields or

wave-particle interaction. In recent years localized auroral spots or arcs were found by space-based auroral imagers outside of the ovals in areas that are generally not covered by ground-based imagers or photometers. These auroral phenomena outside of the oval attracted more and more attention as their location and temporal behavior point to various different generation processes. Some of this localized aurora responds directly to varying solar wind conditions while others are more related to internal magnetospheric processes. This review will summarize the knowledge of these localized auroral phenomena and discuss recent findings from high spatial and temporal resolution observations by large ground-based systems.

## Fukuda, Yoko

### Event and statistical studies on the energy and pitch angle distribution properties of electrons in the Inverted-V region

Fukuda, Yoko[1]; Hirahara, Masafumi[1]; Asamura, Kazushi[2]; Sakanoi, Takeshi[3]; Yamazaki, Atsushi[2]; Seki, Kanako[4]; Ebihara, Yusuke[4]

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4. Nagoya Univ., Tokyo, Japan

Inverted-V electrons are accelerated by field-aligned potential difference. It is thought that these fine structures of their energy and pitch angle distribution are due to electrostatic structures and their variations. Lin and Hoffman(1979) investigated the time variations of flux ratio of downward electron component to perpendicular electron component in the Inverted-V region. There are, however, also the results which are inconsistent with the acceleration process due to field-aligned potential difference. For example, Whalen and Daly(1979) showed that the pitch angle distributions of precipitating electrons are field-aligned near the edge of an auroral arc, while they are isotropic pitch angle distributions at the center of the arc. These variations of pitch angle distributions are very interesting in terms of the existence of an additional acceleration mechanism but there are few data focused on the fine scale pitch angle distributions of Inverted-V electrons. It is also important to compare auroral emissions to pitch angle distributions for more advanced understandings of auroral acceleration region. We used the data based on Reimei simultaneous observations for auroral particles and emissions with high spatial and time resolutions in our study. In this presentation, we will summarize statistically the variation patterns of the energy and pitch angle distribution in the Inverted-V region. We found that the energy distributions of Inverted-V electrons have the fine structures associated with the variations of auroral emissions. We could also find the characteristic variations of pitch angle distribution in Inverted-V region. Particularly at the edges of Inverted-V region energy fluxes of downward electrons are distinguished. As Reimei moves toward the center of Inverted-V region, energy fluxes of perpendicular electrons increase and their characteristics energies increase at the same time. These signatures also exist even when field-aligned electrons by inertial Alfven wave acceleration [Asamura et al., 2009] are not observed. At the edges of inverted-V region, the electric field is perpendicular to the magnetic field. It is difficult to understand that electrons are accelerated along the magnetic field at these regions. On the other hand, at the center of the inverted-V region isotropic pitch angle distributions are found around characteristics energy of inverted-V electrons. We will also discuss the relations of the structures and variations of auroral emissions to the properties of electrons in the Inverted-V region.

## Ge, Yasong S.

### BBFs, Dipolarization Fronts and their Auroal effects in the Global MHD simulation of February 27, 2009 Substorm

Ge, Yasong S.[1]; Raeder, Joachim[1]; Angelopoulos, Vassilis[2]; Gilson, Matthew L.[1]; Runov, Andrei[2]

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A global MHD simulation has been performed to investigate the THEMIS substorm on February 27, 2009. During this substorm the conjugated observations from the space and on the THEMIS ground observatories are available. The location and time of this substorm onset can be determined based on these observations. The initial auroral brightening is found at around 07:49 UT in the field of view of Fort Smith station (FSMI), with a pre-existing auroral arc located equatorward. A couple minutes later, the in situ observations recorded a sharp dipolarization front sunward passing through THEMIS spacecraft, which travels almost 10 RE in the magnetotail. In this study our global MHD model, i.e., OpenGGCM, driven by the real-time solar wind/IMF conditions, is able to reproduce the key features of these substorm signatures, including the auroral pseudobreakup 30 minutes before the major onset, the major auroral breakup at FSMI with the close onset time as the observations, and a strong earthward Bursty Bulk Flow (BBF) and dipolarization fronts that cause the substorm onset signatures. It is found in the simulation that the auroral breakup is caused by the strong flow shear and the flow vortices which form as the BBF moves earthward. Investigation of the tail BBF and its dipolarization front (DF) reveals that the bipolar change of the Bz component ahead of the DF can be produced by the interaction between two distinct plasmas from separate X lines: the anti-sunward moving southward flux tubes in the tailward flows emanating from an inner magnetic reconnection region, and the sunward traveling dipolarized tubes within the front of a strong earthward BBF that originates in a mid-tail reconnection region.

## Genot, Vincent

### Numerical simulations of wave/particle interaction in inhomogeneous auroral plasmas

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Investigating the process of particle acceleration in auroral regions, we study the spatio/temporal evolution of the interaction of Alfvén waves (AW) with a plasma inhomogeneous in a direction transverse to the static magnetic field. Such an inhomogeneity is typical of auroral density cavities on which Cluster observations have recently added new constraints on the temporal stability. From Particle In Cell simulations, we show that the AW propagation on sharp density gradients leads to the formation of a significant parallel (to the magnetic field) electric field (E-field). It results from an electric charge separation generated on the density gradients by the polarization drift associated with the time varying AW E-field. Its amplitude may reach a few percents of the input AW E-field. This parallel component accelerates electrons up to keV energies over a distance of a few hundreds Debye lengths, and induces the formation of electron beams. These beams trigger electrostatic plasma instabilities which evolve toward the formation of nonlinear electrostatic structures. Different numerical configurations have been considered to assess the influences of 1/ a localized cavity, 2/ a localized Alfven pulse, 3/ the mass ratio. From favorable comparisons with observations, this study elucidates a possible general scenario to account for particle acceleration and wave dissipation in inhomogeneous plasmas.

## Gilson, Matthew L.

### Simulation of the longitudinal splitting of the nightside proton aurora during a substorm seen by the IMAGE spacecraft

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We use the OpenGGCM global MHD code to model the magnetosphere during substorms using input from solar wind monitors. Using the MHD fields and assuming the loss cone is a simple function of $\kappa = \mathrm{sqrt}(Rc/\rho)$ (Rc is the field radius of curvature and $\rho$ is the average ion gyroradius), we calculate the precipitation from protons scattered by fieldline curvature during a substorm seen by the IMAGE spacecraft on April 28, 2001. During the substorm, the proton aurora splits in local time shortly after onset. The simulation reproduces the observed splitting and shows that it is caused by the local time expansion of the substorm current wedge. We also examine the relationships between the simulated proton and electron precipitation.

## Goldstein, Melvyn L.

### The Origin of High-Energy Electrons in Reconnection Events in Earth's Magnetic Tail and Their Fate in the Inner Magnetosphere

Goldstein, Melvyn L.[1]; Ashour-Abdalla, Maha[2]; Hwang, Kyoung-Joo[1, 4]; Figueroa-Viñas, Adolfo[1]; Schriver, David[2]; El-Alaoui, Mostafa[2]; Zhou, Meng[2]; Pickett, Jolene[3]

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Magnetic reconnection in magnetized plasmas represents a change in magnetic field topology and is associated with a concomitant energization of charged particles that results from a conversion of magnetic energy into particle energy. Using data from THEMIS mission together with global and test particle simulations, we have demonstrated that electrons can be energized in via betatron acceleration to energies of 100 keV or highter as dipolarization fronts sweep Earthward into the inner magnetosphere. The particle distributions in the inner magnetosphere are non-Maxwellian and consistent, with betatron accleration, have an excess of perpendicular versus parallel temperatures with respect to the local magnetic field. Also present in the data, are a variety of electromagnetic emissions. We investigate the possible wave-particle interactions that might affect the observed distributions with the goal of ascertaining if the observed particles are likely to be related to the production of aurora.

## Grant, Jeff

### Relating the equatorward boundary of the diffuse redline aurora to its magnetospheric counterpart

Grant, Jeff[1]; Donovan, Eric[1]; Spanswick, Emma[1]; Jackel, Brian[1]

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Auroral boundaries are the ionospheric footprint of sharp gradients in magnetospheric properties. Examples include the poleward border of the diffuse "redline" (630 nm) aurora and equatorward boundary of the proton aurora which have been shown to be excellent proxies for the ionospheric projections of the open-closed and ion isotropy boundaries, respectively. Recent ground-based ASI and MSP observations have shown that there is often an arc collocated with the equatorward boundary of the diffuse redline aurora (onset arcs for example are frequently located at this boundary). Even a cursory consideration of the location of the equatorward boundary of the redline aurora relative to that of the proton aurora leads us to the conclusion that the redline equatorward boundary is not the ionspheric

projection of the earthward edge of the electron plasma sheet. In this paper, we use ground-based optical, together with in situ topside ionospheric and magnetospheric plasma observations to identify the magnetospheric feature that most likely corresponds to the equatorward boundary of the redline aurora.

## Gunell, Herbert

### Vlasov simulations of magnetic field-aligned electric fields

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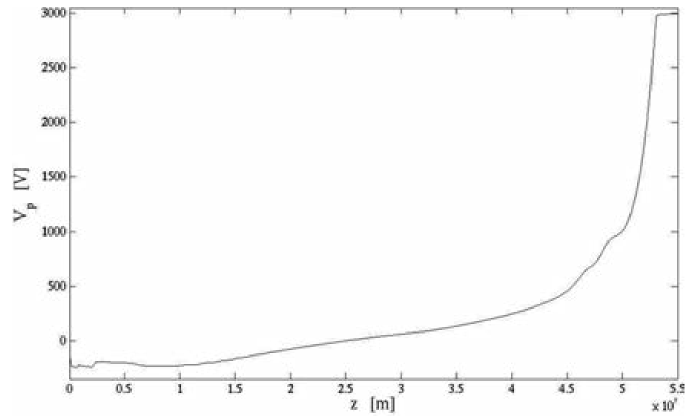
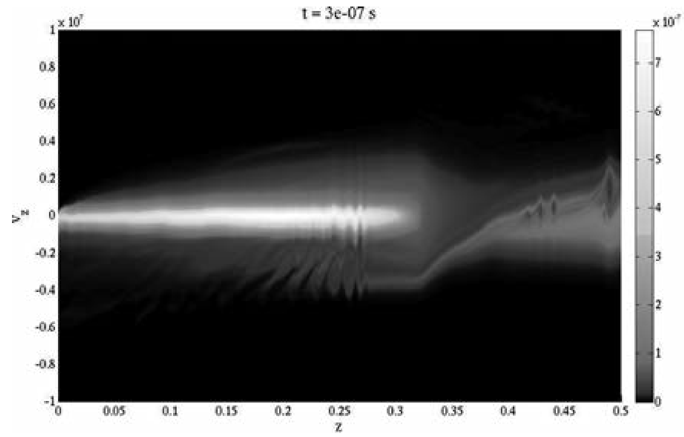
Electrostatic fields that are parallel to the earth's magnetic field are known to exist in the auroral zone and contribute to the acceleration of auroral electrons. Parallel electric fields can be supported by the magnetic mirror field, creating potential drops extending over great distances (*Alfvén and Fälthammar, Cosmical Electrodynamics*, 2nd ed., 1963). Stationary kinetic models have been used to study the current-voltage characteristics of the auroral current circuit (*Knight, Planet. and Space Sci.*, vol. 21, 741-750, 1973). Later, fluid and hybrid models have been used in the study of potential drops and of Alfvén waves and their relation to the formation of potential drops (*e.g., Vedin and Rönnmark, JGR*, vol. 111, 12201, 2006). Recent observations have shown that field-aligned potential drops often are concentrated in electric double layers (*e.g. Ergun, et al., Phys. Plasmas*, vol. 9, 3685-3694, 2002). Vlasov simulations of the part of the flux tube where most of the auroral acceleration takes place have been performed recently (*Main, et al., PRL*, vol. 97, 185001, 2006). We present results from Vlasov simulations using a model that is one-dimensional in configuration space and two-dimensional in velocity space. The model is verified by comparison with a double layer experiment in the laboratory, and it is applied to the auroral field lines. We model a flux tube from the equator to the ionosphere. By introducing a relative dielectric constant $\varepsilon_r$ such that $\varepsilon=\varepsilon_0\varepsilon_r$ we can run the simulation on a coarser spatial grid and with a longer time step, because $\lambda_D \sim \sqrt{\varepsilon_r}$ and $\omega_p \sim 1/\sqrt{\varepsilon_r}$ (*Rönnmark and Hamrin, JGR*, vol. 105, 25333-25344, 2000) We start with a large $\varepsilon_r$ value, filling the simulation region with plasma from the ends. We then conduct a series of simulation runs, successively decreasing $\varepsilon_r$ toward realistic values. Thus, we arrive at a solution, without relying on assumptions about the distribution function in the interior of the simulation region.



Simulated potential along an auroral flux tube.



Electron velocity distribution function in a simulation of a double layer experiment.

## Gurnett, Donald A.

### Aurora, Electron Beams, Auroral Hiss, and Parallel Electric Fields Associated With Saturn's Moon Enceladus

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The Cassini spacecraft, which is in orbit around Saturn, has revealed that the small moon Enceladus is ejecting plumes of water, water vapor, and ice crystals into the magnetosphere. This ejected material, which is the primary source of plasma in Saturn's magnetosphere, is known to have some very interesting local interactions with Saturn's rotating magnetospheric plasma, including the generation of aurora at the foot of the magnetic field line passing through the moon. In this paper we analyze a series of close passes by Enceladus in which we directly detect the field-aligned currents and low energy electron beams caused by the interaction with the streaming magnetospheric plasma.

On several passes the plasma wave instrument also detected whistler-mode auroral hiss emissions with v-shaped frequency-time spectrums very similar to those generated by electron beams in the terrestrial auroral regions. By performing ray tracing analyses of the v-shaped spectral features we have been able to remotely determine the likely region where parallel electric fields accelerate the electron beams responsible for the auroral hiss and the aurora.

## Gustavsson, Bjorn

### Multi-instrument observations of Black Aurora, modelling and results

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Black auroras are recognized as spatially well-defined regions within a uniform diffuse auroral background where the optical emission is significantly reduced. Black auroras typically appear post-magnetic midnight and during the substorm recovery phase, but not exclusively so. For the first time multi-monochromatic optical imaging of black aurora has been combined with ionospheric modelling based on data from the incoherent scatter radar of EISCAT. By combined inversion of the electron density profiles to energy spectra of precipitating electrons and modelling of the optical emissions we compare the observed reductions and the reductions predicted from the theories that black aurora is caused by a retarding electrical field or by inhibition of pitch angle scattering.

## Haerendel, Gerhard

### Five Types of Auroral Arcs and their Sources

Haerendel, Gerhard[1]

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Out of the large variety of auroral forms five prominent types are selected and tentatively associated with source regions in the outer magnetosphere and tail. They are: (1) the equatorward moving growth phase arcs; (2) the onset arc; (3) the poleward arc of the substorm bulge carrying much of the auroral electrojet; (4) Alfvénic arcs at the poleward edge of inverted-V arcs; and (5) arcs embedded in the convection along the auroral oval. Except perhaps for the growth phase arc, all arcs are powered via field-aligned currents, whether quasi-stationary or propagating, and by the release of the associated shear stresses. There are only two basic types of such current systems. They were defined by Boström in 1964. In Type I the currents close along the arc, in Type II they close across the arc. Mixed cases are probably common. The task in relating ionospheric with magnetospheric processes is to identify the relevant current system and the forces driving the generator. This is my present understanding: Class (1) is probably only the trace of high precipitation from the earthward edge of the stretched tail plasma sheet. Arcs (2), (4), and (5) are dominated by Type II systems, whereas a Type I system is feeding the poleward arc at substorm breakup (3). It is not clear at this time whether onset arcs are not mostly Alfvénic in nature. In any case, classes (2) and (4) seem to the driven by plasma inflow out of the central current sheet of the tail into more dipolar field. Sunward pointing pressure forces are the ultimate driver of arcs of class (5). The driving force of arc (3) is the magnetic pressure of the tail compressing a high-beta plasma layer created at the interface of tail and magnetosphere by the plasma ejected from the tail in the substorm process. Classes (2), (3), and (4) have in common that they are instrumental in removing excess flux tube entropy from the source plasma.

## Hargreaves, John K.

### Dynamic behaviour of patches of auroral radio absorption observed by imaging riometer and incoherent-scatter radar

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2. John Tyndall Institute for Nuclear Research, University of Central Lancashire, Preston, United Kingdom
3. Department of Physics, University of Lancaster, Lancaster, United Kingdom

The dynamic nature of auroral radio absorption, usually observed by means of spaced riometers, has been appreciated since the late 1960s. The cause has remained in some doubt, however. During a campaign of D-region observations with the European Incoherent Scatter radar (EISCAT) in March 2008, supported by the imaging riometer system (IRIS) at Kilpisjarvi, Finland, absorption patches tens of kilometers across in the morning sector were observed to drift across the field of view of the imaging riometer in a principally west-east direction. After a brief historical introduction summarising previous results from observations with wide-beam riometers spaced across wide and narrow baselines, examples are presented of the new observations and of the magnitude and location of the absorption patches within the 240-km square viewing area (at D-region altitudes) of the imaging riometer. From these data the speeds in west-to-east and north-to-south directions are determined. Of 11 dynamic patches observed in sequence, 8 showed eastward motion with speeds averaging about 20 km/minute, whereas the final 3 all moved westward at considerably lower speeds. These latter features also showed a small southward (equatorward) component of velocity. The question of the drift mechanism is considered with the aid of the incoherent scatter radar data, and with reference to simultaneous measurements of F-region drift by the SuperDARN radar system. The electron density profiles provided by the EISCAT radar indicate that the energy of electrons causing the D-region absorption is too high for the observed absorption drift to be due to the gradient-curvature drift of

trapped electrons (a mechanism which has long been a candidate for longitudinal absorption drift, and is still not ruled out for effects over greater distances where the apparent drift speeds are larger). In comparisons with the F-region velocity as determined by the SuperDARN radar system it is noted that peaks in the absorption often occur close to maxima in the velocity given by SuperDARN, The directions of motion also agree, but the speeds only agree well for a short period in the early morning. Comparisons between absorption drifts and SuperDARN measurements are being continued using a larger set of data.

## Henderson, Michael G.

### Observing the Magnetospheric Plasmas Associated with Different Types of Aurora (*Invited*)

Borovsky, Joseph E.[1]; Henderson, Michael G.[1]

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In the winter of 1994-1995 the University of Alaska fielded an all-sky camera at Eagle, Alaska to monitor the auroral activity at the magnetic footpoint of the geosynchronous-orbit spacecraft 046 in the equatorial magnetosphere. The footpoint location on all-sky images was determined with the Tyganenko T89 model. Several types of aurora were observed at the footpoint: diffuse aurora, flutes, drifting patches, pulsations, and arcs. Entries of the footpoint into the low-latitude edge of the diffuse aurora corresponded to the spacecraft exiting the plasmasphere and entering the electron plasma sheet. Pulsating aurora were associated with the presence of substorm-injected electrons and pancake distributions of plasma-sheet electrons, but not with cold ions. Most interesting were the passage of auroral arcs across the footpoint. This corresponded to sudden large changes in the electron temperature of the plasma sheet in the equatorial magnetosphere, without changes in the ion properties. This observation implies that auroral arcs may be associated with electron pressure gradients in the magnetosphere.

## Henderson, Michael G.

### Auroral Substorm Onsets, Pseudobreakups and Auroral Precursor Activity (*Invited*)

Henderson, Michael G.[1]

1. Los Alamos National Laboratory, Los Alamos, NM, USA

Many different types of auroral features are routinely observed during disturbed conditions. These include poleward boundary intensifications (PBIs), north-south aligned auroral structures (or ``streamers”), auroral torches, omega bands, pulsating patches, embedded auroral onsets and more. The detailed nature of how PBIs and streamers form has already been extensively studied and it has been shown that PBIs and auroral streamers can evolve into auroral torches and omega bands. What is less well understood is how these various auroral forms may or may not be related to subsequent auroral breakup signatures. A few studies over the past 40 years have reported breakup precursor activity, but a definitive answer on cause and effect is still outstanding. Here we present observations that show: (1) The vast majority of streamers definitely do not lead to substorm onset; (2) Some onsets can be found for which precursor activity was present; and (3) Many of the recently reported cases of streamer-induced onsets are not real onsets, but are rather the type of streamer activity that has already been reported. Interpreting auroral streamers as ionospheric manifestations of bursty bulk flows in the tail (due to earthward propagation of low-entropy flux tubes), we conclude that that flow braking mechanism of the renovated NENL model cannot by itself be the cause of the auroral breakup and subsequent expansion.

## Hiraki, Yasutaka

### Characteristics of auroral arcs formed by the feedback instability with extended MHD effects

Hiraki, Yasutaka[1]; Watanabe, Tomohiko[1]

1. National Institute for Fusion Science, Toki, Japan

The ionospheric feedback instability has been presented for a mechanism of destabilization of Alfven waves penetrating into the ionosphere due to the resonance with convection electric field drifts [Lysak, 1991, 2002; Watanabe, 2010, and references therein]. The horizontal length scale of the instability ranges 1-100 km, which covers the scale of auroral arcs along with their filamentary structures. The growth timescale varies from 1-10 sec for high-frequency cavity modes to a few minutes for the lower harmonics. Lysak [1991] performed the linear analysis in the slab magnetic field geometry including the ionospheric resonant cavity, a rapid decrease in the Alfven velocity below a height of ~1 Re. They clarified the effects of resonant cavities on the frequency and the growth rate of Alfven waves as a function of Pedersen conductance, convection field, and perpendicular wave number. Watanabe [2010] performed a nonlinear simulation of the feedback instability with the two-field reduced-MHD model in the three-dimensional slab geometry. They demonstrated that some spontaneous behaviors as a rolling-up of vortices appear at the magnetospheric equator, and secondary auroral structures are produced by a nonlinear mode coupling. Extending the model into the dipole magnetic field geometry, we revisited the linear eigenmode analysis including the ionospheric and magnetospheric resonant cavities [Hiraki and Watanabe, 2010 in preparation]. The magnetospheric cavity is a classical problem associated with a trapping of ULF waves [Chen and Hasegawa, 1974] and a driver of auroral intensification [Samson et al., 1992]. Recent high-resolution video imagery reveals an excitation of small-scale auroral structures less than 1 km [Liang et al., 2008; Sakaguchi et al., 2009], and its relationship with kinetic Alfven waves are vigorously studied [Rankin et al., 1999; Chaston et al., 2006; Lysak and Song, 2008; Streltsov et al., 2008]. At the ionospheric cavity region, the electron inertia effect has a crucial role for the growth of such a small wave (<1 km), whereas the effect of the induction current should be included since the Alfven velocity is as high as 10^8 m/s. We include these extended

MHD effects into our reduced-MHD model and make a linear analysis of the feedback instability for kinetic Alfven waves. In this talk, we present the results of the dispersion relation compared with the ideal MHD case. We would also introduce a current result of the nonlinear simulation of the shear Alfven wave in the dipole geometry.

## Holmes, Jeffrey M.

### Relative shock-induced proton and electron auroral propagation: combined ground- and space-based optical measurements

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Aurorae observed during the passage of interplanetary shocks exhibit interesting features that are different from both typical auroral activity on the dayside and substorm aurora on the nightside. Following a near magnetic noon onset, the occurrence of emissions created by precipitating protons and electrons are observed to propagate tailward, along the auroral oval with speeds of several km/s, similar to the shock propagation speed. We report on analysis of shock aurora events previously studied using solely space-based ultraviolet auroral imagery. While such images provide an excellent hemispheric picture of the evolution of the auroral propagation, there can often be minutes between images of the same wavelength passband. UV imagery are combined with data from up to six ground-based meridian scanning photometers (MSPs) in the Northern Hemisphere, with time resolutions as low as 16 seconds, in order to further refine the timing calculations of shock-enhanced auroral propagation speed along the oval. Furthermore, the multispectral nature of the MSPs, including the presence of a Balmer beta channel, enable the descrimination between proton and electron aurora. Evidence of the predicted preferential propagation of proton (electron) aurora along the duskside (dawnside) auroral oval is presented and compared to previous spacecraft-based studies using UV imaging.

## Hwang, Kyoung-Joo

### Particle energization and wave-particle interactions associated with substorm dipolarization fronts

Hwang, Kyoung-Joo[1, 2]; Goldstein, Melvyn L.[1]; Ashour-Abdalla, Maha[3]; Figueroa-Vinas, Adolfo[1]; Pickett, Jolene S.[4]

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4. Department of Physics and Astronomy, University of Iowa, Iowa City, IA, USA

Dipolarization fronts (DFs) characterized by a sharp jump in Bz, a drop in density, and often a following earthward fast flow, are a phenomenon commonly detected near the equatorial plane of Earth's tail plasma sheet. Sometimes, DFs have been associated with global substorms. We present case studies of Cluster observations of DFs that are detected in different locations, and related to substorm auroral brightenings. Using multi-spacecraft analyses together with simulations, we investigate the propagation and evolution of these DFs and the acceleration of electrons and ions that results from such magnetic-field changes. Non-Maxwellian electron and ion distributions that result from the particle energization associated with the DFs are found to be unstable to a range of electrostatic and/or whistler instabilities. The electrostatic broad-band noise enhanced at frequencies below and near the lower-hybrid frequency is observed at or very close to the DFs. Behind DFs emissions near the electron cyclotron frequency and in a whistler-mode range are noticeable and appear to be linked to ring-like distribution of electrons. These waves are thought to play a role in further energization of the particles. We solve the wave dispersion relations for the observed plasma distributions to identify wave modes that might be responsible for the electron and ion acceleration and heating. Such a study can provide insights into those particle acceleration mechanisms associated with substorm dipolarization, and, in turn, the effects of those acceleration mechanisms on the structure and evolution of DFs.

## Ieda, Akimasa

### Field-aligned Currents During an Intense Substorm as Estimated from Global Auroral Images and Ground Magnetic Observations

Ieda, Akimasa[1]; Kamide, Y.[1]; Hori, T.[1]; Seki, K.[1]; Miyoshi, Y.[1]; Fujii, R.[1]; Lummerzheim, D.[2]; Strangeway, R. J.[3]; Fillingim, M. O.[4]; Parks, G. K.[4]; McFadden, J. P.[4]; Carlson, C. W.[4]

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2. University of Alaska, Fairbanks, AK, USA
3. University of California, Los Angels, CA, USA
4. University of California, Berkeley, CA, USA

The spatial distribution of field-aligned currents (FACs) relative to auroras is studied for an intense substorm, whose expansion onset began at 0724 UT, January 12, 1997. We first

estimated the height-integrated ionospheric Hall and Pedersen conductances from ultraviolet images taken by the Polar satellite. We also calculated the equivalent current system at the ionospheric altitude from ground magnetic field perturbations on the basis of the spherical harmonics analysis. To derive FACs, we then employed Ohm's law for the ionosphere, applying the Kamide-Richmond-Matsushita (KRM) method to these input conductances and equivalent currents. A preliminary study indicates that a downward FAC is located near the poleward edge of an auroral bulge and that an upward FAC is located inside the bulge during the expansion phase of the isolated substorm. This latitudinal pattern of FAC is consistent with the meridional Hall current loop caused by dipolarization or reconnection in the magnetotail, but is in the opposite sense to the expectation from the current wedge-associated Cowling channel.

## Jahn, Jörg-Micha

### Auroral Proton Precipitation "Viewed" Differently: Quantifying Ion Precipitation Using ENA Emissions

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4. University of Bergen, Bergen, Norway

Precipitation of keV protons into Earth's upper atmosphere creates the strongest emissions of energetic neutral atoms (ENA) in the magnetosphere-ionosphere system. The rapidly increasing density of atomic oxygen provides an effective charge exchange target that results in a significant ENA yield. Since the atmosphere below approximately 600 km altitude is optically thick for ENAs, precipitation-induced ENA emissions interact with the local neutral medium, complicating remote sensing of these emissions. Nevertheless, measurements of these ENAs provide direct access to the source magnetospheric ion distributions. Just as with in situ measurements, we directly measure the particle energy spectrum. Unlike in situ measurements, however, ENA measurements can simultaneously cover a much wider local time range of the precipitation region, albeit at the expense of coarser spatial resolution. After introducing the theoretical and practical framework of making and using precipitation-induced ENA emissions, we will discuss measurements for the 2003/2004 northern hemisphere winter season. At that time the IMAGE spacecraft was for a few months passing over the center of the northern and southern auroral regions in a near-symmetric fashion. This provided ENA measurements from keV ion precipitation in both hemispheres within 90 minutes of each other, covering an altitude range of 3,000 to 10,000 km, yielding at times a full 360 degree ENA view of the precipitation region.

## Jaynes, Allison N.

### Observations of Neutral Upwelling in the Cusp Region: High-Altitude Atomic Oxygen Signatures Observed by the SCIFER2 Sounding Rocket

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The SCIFER2 sounding rocket was launched into a Poleward Moving Auroral Form (PMAF) event on January 18, 2008. As is typical, the event was characterized by the presence of soft electron precipitation, driving discrete arcs at 630 nm. The rocket payload, which included a UV photometer as well as several other instruments, flew in the vicinity of the dayside cusp and reached an apogee of approximately 1500 km. The photometer was included on the payload in order to explore the possibility that sunlight might scatter from upwelling neutral gases as a result of the electron precipitation (and associated microphysical processes). Highly structured UV emissions were measured emanating from sources located several hundred km to 1000 km or more above the ground. In this study, we examine ground and rocket data to determine the source of these emissions. The structures appear to be associated with sunlight scattered from high-altitude (upwelling) neutral gases. We include analysis of all-sky images to correlate absolute brightness of auroral forms with UV emission data.

## Jiang, Feifei

### The relative spatial location of the inner edge of the electron plasma sheet to the possible magnetospheric source region of the equatorward pre-existing auroral arc

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One distinct feature of an auroral substorm is the brightening of a pre-existing, stable arc at onset [Akasofu, 1964]. The pre-existing arc that brightens is usually embedded within several discrete aurora arcs located in the equatorward region of the aurora zone. These narrow auroral arcs often appear during a substorm growth phase, persist and show little fluctuations until the expansion onset. Understanding the nature of the pre-existing auroral arcs is crucial to understanding the physical processes of magnetospheric substorms. However, the magnetospheric source region of these equatorward pre-existing arcs remains a puzzle. Previous studies have suggested that the growth-phase arcs map to a transition region between a dipole-like field and tail-like topology in the tail (~5 Re to ~10 Re on the night side [Lyons and Samson, 1992]). In this study, we

have used the THEMIS all-sky white light imagers to look for cases where one observes discrete, relatively steady growth-phase arcs and the THEMIS probes in the inner magnetosphere to identify the inner edge of the electron plasma sheet during the THEMIS tail seasons in 2008 and 2009. We map the inner edge of the electron plasma sheet to the ionosphere and map the growth-phase arcs to the plasma sheet to investigate the relative location of the pre-existing auroral arcs to the inner edge of the electron plasma sheet.

## Jones, Sarah

### A Statistical Study of Large-scale Aspects of Pulsating Aurora Using the THEMIS All-sky Imager Array

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Pulsating aurora has traditionally been thought to occur during the auroral substorm recovery phase. A statistical study presented here describes the temporal and spatial evolution of pulsating events using two THEMIS ASI stations along roughly the same invariant latitude, using data from September 2007 through March 2008 as identified with the Gillam camera. It is shown that the source region of pulsating aurora drifts or expands eastward, away from magnetic midnight, for pre-midnight onsets and that the spatial evolution is more complicated for post midnight onsets, which has implications for the source mechanism. The most probable duration of a pulsating aurora event is roughly 1.5 hours while the distribution of possible event durations includes many long (several hours) events. One particular case which is studied in detail, from February 11, 2008, consists of a pulsating aurora event which begins with no obvious substorm precursor within the THEMIS all-sky array and expands to eventually cover at least 10 hours MLT and lasts over 15.5 hours from start until camera turnoff for daylight. These observations may suggest that pulsating aurora is not a substorm recovery phase phenomenon but rather a persistent, long-lived phenomenon that may be temporarily disrupted by auroral substorms.

## Kaeppler, Stephen R.

### Current Closure in the Ionosphere: Results from the ACES Sounding Rocket

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The Auroral Current and Electrodynamics Structure (ACES) rockets were launched into a dynamic multiple-arc aurora, from Poker Flat Research Range, AK on January 29, 2009. The ACES rocket mission, in conjunction with the PFISR Radar, was designed to observe the three dimensional current system of an auroral arc during quiet-time conditions. ACES utilized two well instrumented payloads flown along very similar magnetic field footprints, but with different apogees. The higher altitude payload (apogee 330 km) took in-situ measurements of the plasma parameters above the current closure region to provide the input signature into the lower ionosphere. The low altitude payload (apogee 130 km) took similar observations within the current closure region, where cross-field currents can flow. We present results comparing the electric and magnetic fields, density measurements, and electron particle data on the two payloads . We also present data from all sky imagers of the evolution of the auroral arc as the payloads passed through similar regions of the auroral arc. We examine an event in the high altitude payload which may be the signature of electron acceleration by means of Alfvén waves. We also examine these measurements to understand ionospheric conductivity and how energy is being deposited into the ionosphere through Joule heating. We further compare the plasma measurements between the high and low altitude payload to make inferences about current closure geometry.

## Kan, Joseph R.

### Dipolarization onset initiated by intense Cowling electrojet current loop: Substantiated by a THEMIS substorm observed on March 1, 2008

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We present THEMIS observations of a substorm on March 1, 2008 to substantiate the M-I coupling substorm model characterized by the dipolarization onset initiated by the time-dependent Cowling electrojet current loop (CECL), as proposed by Kan (2007). The THEMIS observations include: Cowling electrojet current intensifies as the -AL index enhances from ~250 nT at ~03:57 UT to a peak value ~600 nT at ~04:02 UT and remains at the enhaced level till ~04:30 UT. The auroral substorm onset is quantified by the integrated auroral brightness onset at ~03:57:57 UT based on the THEMIS ASI at GILL Observatory. Dipolarization onset is estimated at ~03:59:17 UT based on the BZ and the magnetic tilt angle at THEMIS-D. The time delay between the integrated auroral brightness onset at GILL and the dipolarization onset at THEMIS-D is estimated at ~80 sec. The Alfvén travel time based on the AM02 field model, from the ionospheric footprint to the THEMIS-D is estimated at ~80.3 sec. The Cowling eIectrojet intensifies by the earthward convection driven by the NEXL at ~20 ± 5 RE during the growth phase. Interactions between the CECL and the near-Earth plasma sheet involve conversion of the incident Alfvén mode into the Fast/Slow MHD modes to reduce the cross-tail current in the dipolarization region. Estimation of the cross-tail current "reduction" in the dipolarization region indicates that the reduced current consists of: (A) "Disruption" of the cross-tail current to match the field-aligned current in the CECL, and (B) "Redistribution" of the cross-tail current from the dipolarization region to enhance the ring current during a substorm. The CECL after the dipolarization onset, is connected to the cross-tail current as the observed substorm current wedge. The Pi2 pulsation onset at ~03:53:41 UT on the ground at GILL is a precursor of the auroral substorm onset. The Pi2 onset at ~03:56:26 UT in space at THEMIS-D is a precursor of the dipolarization onset.

## Karlsson, Tomas

### Overview of the auroral acceleration region (*Invited*)

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Discrete auroral arcs are associated with precipitating electrons which have undergone an acceleration parallel to the geomagnetic field. For the quiet auroral arc, there is ample observational evidence that this acceleration takes place by a magnetic field-aligned electric field, associated with a quasi-static U-shaped potential structure. The acceleration typically takes place at an altitude of 1-2 Earth radii. We here present some properties of this auroral acceleration region, from the perspective of both observations and simulations and modeling. These include the plasma environment, cavity formation, the current understanding of the physics behind the creation of the parallel electric field, and temporal properties. We finally present some recent results from Cluster multi-point measurements inside the acceleration region, and some statistics on the temporal stability of the field-aligned currents, the continuity of which are ultimately responsible for the creation of the parallel electric field.

## Kataoka, Ryuho

### Ground-based high-speed imaging observation of auroral microstructures

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It has been known that auroral microstructures sometimes show rapid variations beyond Pc1 frequency range, possibly associated with electromagnetic ion cycrotron (EMIC) waves and dispersive Alfven waves (DAWs). In order to resolve the key optical features of the electron acceleration mechanisms, it is essential to realize high-speed imaging with sampling rate beyond the classic video frame rate of 30 Hz. We conducted a coordinated observation of ~100 Hz high-speed imaging of auroral microstructures at Poker Flat Research Range (PFRR) during a 2010 winter season from late January to middle of April. Two wavelengths of 845 nm and 670 nm are observed by two different EMCCD (Electron Multiplying Charge Coupled Device) cameras to estimate the characteristic energy of precipitating electrons and to detect a possible time-of-flight effect. Many types of interesting features were found during breakup aurora. Splitting of striation structures may be

associated with feedback instabilities, and rapidly expanding packets of elemental arcs may be associated with DAWs. We found an apparent time delay between flickering auroral images of 670 nm and 845 nm, probably due to the time-of-flight effect, and it is potentially useful to determine the height of acceleration region of flickering aurora. In this presentation, we will report the first results of analysis of such new findings. We will also report preliminary results from a new optical experiment at PFRR in November 2010, where we are planning to conduct a ~250 Hz imaging of auroral microstructures for the first time to search unexpectedly fast auroral phenomena.

## Kauristie, Kirsti

### A statistical study of Traveling Ionospheric Disturbances based on EISCAT Svalbard Radar data

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We present a statistical study of Traveling Ionospheric Disturbances (TIDs) as observed by the EISCAT Svalbard Radar (ESR) during the continuous IPY-run (March 2007 - February 2008). We have developed a semi-automatic filtering routine for searching wave activity with period period times in the regime of Atmospheric Gravity Waves (AGW).From the filtered daily records we have selected the events with downward propagating phase fronts to our AGW-TID data base. This data base shows that AGW-TID signatures are common in the polar cap ionospheric observations especially in the field-aligned ion velocity data (244 events) but they can be observed also in electron density (26 events), electron temperature (12 events) and ion temperature (26 events). During the IPY campaign (in solar minimun conditions) clearly more AGW-TID events were recorded during the summer months than during the winter months. The distribution of the dominating period times has two peaks, one around 30-40 min and the other around 1.1-1.3 h. The diurnal occurrence rate has a deep minimum in the region of magnetic midnight, which is at least partly explained by irregular auroral activity obscuring the TID signatures from our detection routines. In the poster we review the main results from the statistical survey and present some examples of auroral and electrojet activity during TID/AGW conditions.

## Kepko, Larry

### Linking space-borne and ground-based observations observed around substorm onset to magnetospheric processes

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The combined THEMIS five spacecraft in-situ and ground magnetic and camera arrays have advanced considerably our understanding of the causal relationship between midtail plasma flows, transient ionospheric features, and ground magnetic signatures. In particular, recent work has shown a connection between equatorward moving visible ionospheric transients and substorm onset, in both 6300 nm (Kepko et al., [1009]) and white-light (Nishimura et al., [2010]) emissions. Although both observations detail pre-onset auroral features the interpretations differ substantially. We first provide a brief summary of these observations, highlighting in particular areas where the two observations differ, and suggest reasons for the differences. We then detail how these observations relate to dynamical magnetospheric processes, and show how they constrain models of transient convection. Next, we pull together observations and models of Pi2 generation, SCW initiation and dipolarization to present a self-consistent description of the dynamical processes and communicative pathways that occur just prior to and during substorm expansion onset. Finally, we present a summary of open questions and suggest a roadmap for future work.

## Kirmani, Ahmed R.

### Relationship between Interplanetary Magnetic Field and AE Index

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Solar wind carries the magnetic field of the Sun along with it, known as the interplanetary magnetic field (IMF). Solar wind and IMF affect the earth's magnetic field resulting into the formation of magnetosphere and change its configuration. The high magnitude of the solar wind and appropriate direction of IMF generate storms and substorms in the earth's magnetosphere as a consequence of magnetic reconnections of the open field lines. The storms are measured in terms of disturbed storm time (Dst) index. The reconnection also causes particle acceleration, which gyrate along the field lines and travel to poles of the earth, where they produce aurora. The aurora measured as AE (auroral electrojet) index is another signature of geomagnetic storm. It has been recently proposed that climate change on the earth is related to IMF. However, in order to prove it we

require homogeneous IMF data for a longer period. Currently regular measurement of IMF at L1 orbit is available since 1997 from magnetometer onboard the ACE mission. The other IMF data are varying over orbits. Thus in order to probe the IMF data for the past 100 years period over a fixed location L1 point, we first establish relationship between IMF and AE indices for the period of 1997 to 2010. The AE indices, however, are available for the last more than 100 years. The daily IMF data from 14 August, 1997 as a function of AE indices is studied. We made 5nT bins to reduce noise levels. We found the best fit of these two data sets by a polynomial of the order of 5. This enabled us to predict the IMF to first approximation and to observe the 11 year solar activity. The study has been restricted to finding the relationship between the IMF and AE.

## Kissinger, Jennifer

### Evidence of Harang Discontinuity in Steady Magnetospheric Convection

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It is thought that during steady magnetospheric convection (SMC) events, an extended X-line in the mid-magnetotail (60 RE) results in steady large-scale plasma convection. Increased convection has been shown to manifest in the ionosphere as a Harang discontinuity (HD); however Sergeev et al. (1995) found an absence of the HD during SMC and postulated a wide (15 RE) 'convection throat' centered on midnight. Recently Hughes and Barstow (2002) observed the HD during SMC events using SuperDARN. These conflicting papers contained only a few case studies. We present a statistical analysis of the Harang reversal region for more than 2800 SMC intervals, using SuperDARN radar data. Our events cover years 1997-2007. We examine the progression of the HD as a function of SMC onset. We expect that the HD will persist throughout SMC, indicting widespread continuous convection activity in the tail, and that it will disappear as the SMC ends.

## Knudsen, David J.

### Auroral Arcs: How Much Do We Really Understand?

Knudsen, David J.[1]; Donovan, Eric[1]

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In-situ and optical observations of visible auroral arcs - the most common pre-midnight auroral form - place tight restrictions on candidate theories. For example, electron energies within inverted-V arcs can reach 20-30 keV; they vary characteristically and often symmetrically with latitude; they have typical widths of order 20 km; they are highly elongated in longitude; they can occur as far south as the inner edge of the plasma sheet and as far north as the polar cap (though at lower energies); they often appear in multiple parallel sets of two to five or more; and they can oscillate at flicker, pulsating, or field-line resonance frequencies, though more often they exist with no basic change in form for tens of minutes. These basic properties have been well-known for many decades, yet most auroral theories address only a small subset - often only one - and no theory accounts for them all. As a result, there remains no consensus as to the essential mechanism(s) responsible for auroral arcs. One barrier to progress is a surprising lack of statistical information on basic arc behaviors. This talk describes initial work intended to remedy this situation, and discusses implications for theories of auroral arcs.

## Kubyshkina, Marina V.

### Problems of mapping from magnetosphere to ionosphere during substorms (*Invited*)

Kubyshkina, Marina V.[1]; Sergeev, Victor A.[1]; Donovan, Eric F.[2]

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Mapping issue remains one of the urgent problems in observational magnetospheric physics due to the necessity of joint interpretation of ground based and magnetospheric observations. The only possibility to trace the field line from arbitrary point in magnetosphere is provided by the magnetic field models, basically by widely used family of Tsyganenko models. These models proved to be rather reliable for the average magnetic field in different situations, but if we focus on a certain substorm event, the standard Tsyganenko models do not reproduce the observed substorm-related variations. As a result, these models map a spacecraft to approximately the same point during all phases of a substorm. The real projection is produced by a varying magnetospheric magnetic field and thus may move during a substorm. To further investigate the auroral phenomena, we need to understand what portion of auroral dynamics comes from the displacement of the source of aurora and what portion is due to magnetic field changes. The other problem in mapping with standard Tsyganenko models is that different versions (T89, T96, T01, TS05) will produce different field lines beyond 10 Re, and the mapping differences from may exceed 2-3 degrees in latitude. Together with standard models, we develop the adjusted models, which are individually constructed for each substorm event by modifying the T96 model in order to minimize deviations between observed and modeled magnetic fields. Adjusted models yield much more accurate field at positions of all THEMIS probes, substorm-like variations are present in these models, and stretching and dipolarization are seen in the field line structure. If mapping is done with adjusted models, we get a variable projection of any point in magnetospheric tail, and the variations become larger for more tailward regions. When compared to auroral dynamics during substorm, the motion of spacecraft projections shows correlation with poleward jumps of bright of auroras, suggesting, that considerable part of poleward expansion could be explained by magnetic field reconfigurations. If we compare mapping with standard and adjusted models, the difference is large, it may exceed 5 degrees in latitude for distant tail regions (~ -20 Re), and this difference varies during a substorm. When choosing the best magnetic field model, we usually give preference to the model, which better represents spacecraft variations, though we know that the model, which we use is imperfect. It does not include field-aligned currents and other small scale current structures, which may significantly influence the observed magnetic field in a given point. Thus, the question of possible mapping error, even for the model which will perfectly represent the observed field in all points of observation, remains an important item. The few possibilities to estimate this error may come from rare occasions, when two structures in ionosphere and magnetosphere could be directly related and observed simultaneously. We consider, that the Isotropic boundaries, which are observed at low altitudes, and are related to definite magnetic field line curvature in magnetospheric neutral sheet, may provide a possibility to estimate the error of mapping with a given magnetic field model.

## Kullen, Anita

### On the dynamics of nightside originating transpolar arcs

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During late recovery, the polar cap boundary becomes often thick and patchy, developing bulges that in rare cases develop into nightside originating transpolar arcs. In the present study, nightside originating arcs are studied in detail using global auroral images and DMSP passes over the polar cap. Plasma flows, particle signatures and electric field structures in the recovery bulge as well as on the developing transpolar arc are studied in detail. The particle characteristics of recovery bulges resemble those of the oval of discrete arcs while an already developed nightside originating arc resemble those of dawn-dusk moving transpolar arcs. In most cases, the region between the arc and oval side is filled with particles of subvisual energies, indicating that arc lies on the high-latitude boundary of a strongly polewardly expanded closed field line region.

## Kurth, William S.

### Cassini Observations in and near the Source of Saturn Kilometric Radiation

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Saturn Kilometric Radiation (SKR) is believed to be generated via the cyclotron maser instability on Saturn's low altitude auroral field lines, analogous to Auroral Kilometric Radiation at Earth. While Saturn is a rapidly rotating planet, in many respects similar to Jupiter, Saturn's aurora and SKR are strongly influenced by the interaction of solar wind compression regions with the magnetosphere. Such interactions are characterized by an expansion of the normally narrow auroral oval, primarily on the dawn side, accompanied by an intensification of SKR and an expansion of the bandwidth, most notably toward lower frequencies. Despite spending several months in high inclination orbits regularly crossing auroral L shells, Cassini normally was too high in altitude to make in situ observations of the SKR source region. However, on 17 October 2008 Cassini was on auroral field lines near local midnight during a magnetospheric compression presumably related to the passage of a corotating interaction region in the solar wind. The compression resulted in the extension of the SKR spectrum to below 10 kHz, hence, a source radial distance of about 5 Saturn radii. Detection of the lower frequency bound of the SKR at frequencies below the electron cyclotron frequency suggested that the spacecraft was briefly in the SKR source region. Measurements of the electron distribution function showed evidence of a shell-like feature at energies of several keV and growth rate calculations show that this feature is likely responsible for the observed SKR emissions. We review the Cassini observations of this passage through the SKR source region and compare to terrestrial observations.

## Labelle, James W.

### Ground-Level Detection of Auroral Kilometric Radiation

Labelle, James W.[1]; Anderson, Roger R.[2]

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The Earth's aurorae radiate away up to 1% of their energy in Auroral Kilometric Radiation (AKR), generated via the electron cyclotron maser (ECM) mechanism. AKR was not unambiguously identified until the 1970's because its detection requires a suitably instrumented satellite. The ECM theory and the electron density structure in the source region predict radiation beamed outward that cannot penetrate the increasing magnetic field and electron density near the Earth. Nevertheless, there have been curious observations over the years of AKR-like radio signals detected by ground-based, rocket-borne, and low-earth orbiting satellite-borne instruments, raising the question of whether some mechanism exists by which AKR can penetrate to low altitudes. However in none of these previous cases was AKR detected simultaneously in space and at low altitudes. We identified three examples of AKR-like emissions detected with a ground-based radio receiver at South Pole Station, Antarctica, during a nine-day interval in July, 2004, when the Japanese Geotail satellite, which includes a plasma wave instrument monitoring AKR, had a field of view that included the auroral field lines above the station. The AKR-like emissions detected at ground-level share the same frequency-time structure as simultaneous AKR emissions detected on Geotail 115,000-190,000 km away from the Earth. Slight differences in the frequency extent of the emissions at the two locations can be explained by, for example, plasmaspheric screening of the emissions detected by Geotail. The relative intensities of the emissions observed at the two locations suggest that only a small fraction of AKR propagates downward to ground level. These coincident detections of AKR in space and on the ground require the existence of an as-yet unidentified mechanism to produce the ground-level emissions which are not predicted by ECM theory, suggest that previous AKR-like emissions observed at low altitudes may indeed be AKR, and require revision of the widely-held view that AKR is only detectable from space.

## Labelle, James W.

### MF-Bursts: Terrestrial Auroral Radio Emissions Related to Polar Substorms

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While AKR is by far the most powerful and most studied auroral radio emission, several other types occur including auroral hiss, roar, and MF-burst. Hiss and MF-burst often occur in coincidence at the onset of polar substorms and last for 1-10 minutes. Hiss is right-hand polarized and originates as whistler mode in the ionosphere, whereas MF-burst is left-hand polarized and most likely propagates in the LO-mode in the ionosphere. Recent direction-finding measurements of MF-burst in Alaska show that it starts when the northernmost auroral arc brightens, and its direction of arrival shifts northward as the northernmost arc expands poleward, suggesting that the emission may originate in the Alfvenically-accelerated electron beams in the leading edge of the northernmost expanding arc. Recent fully-sampled observations of MF-burst waveforms show that the emission consists of both an unstructured continuum superposed with structures of ~100-ms duration. The structures are characterized by a ``nose" frequency for which the waves arrive earliest, with frequencies above the nose frequency steeply dispersed and those below it more gradually dispersed. This fine structure provides a means of testing candidate generation mechanisms of MF-burst: ray-tracing shows that the shapes of the leading edges of the burst structures can be plausibly explained by Langmuir waves generated along the topside of the ionosphere and suffering varying group delays before converting to L-mode waves on the ionospheric electron density gradient. The calculations show that this model can only work if the causative electron beams are relatively low energy (<1 keV). Such low energy electrons are consistent, however, with the Alfvenic acceleration process, and the generation of MF burst in the poleward edges of the northernmost arcs therefore may be consistent with other evidence that wave aurora dominates in those arcs. If the model is correct, the shape of the MF-burst is related to the topside electron density profile, analogous to the relation between solar type III emissions and the density profile in the solar atmosphere.

## Lamy, Laurent

### Properties of Saturn kilometric radiation measured from its source region

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On 17 October 2008, the Cassini spacecraft crossed the southern sources of Saturn kilometric radiation (SKR), while flying along high latitude nightside magnetic field lines. In situ measurements allowed us to characterize for the first time the source region of an extra terrestrial auroral radio emission. Using radio, magnetic field and particle observations, we show that SKR sources are surrounded by a hot tenuous plasma, in a region of upward field aligned currents. Magnetic field lines supporting radio sources map a continuous, high latitude and spiral shaped auroral oval observed on the dawnside, consistent with enhanced auroral activity. Investigating the Cyclotron Maser Instability (CMI) as a mechanism responsible for SKR generation, we find that observed cutoff frequencies are consistent with radio waves amplified perpendicular to the magnetic field by hot (6 to 9 keV) resonant electrons, measured locally.

## Lanchester, Betty S.

### Imaging of aurora to estimate the energy and flux of precipitation (*Invited*)

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Most auroral displays contain fine structure when measured at high temporal and spatial resolution. Advances in optical detectors and computer performance allow optical imaging of the aurora at unprecedented spatial (10s of metres) and temporal resolution (50 frames per second). Increased sensitivity allows imaging in narrow spectral regions, isolating emissions with different responses to electrons precipitating with different energies. The ASK (Auroral Structure and Kinetics) instrument has three imagers operating simultaneously in different spectral lines, allowing time-dependent, two-dimensional energy spectrum maps of the auroral precipitation to be generated. This is the best available 'image' of the acceleration processes. Measurements from ASK show detailed filamentation, splitting arcs, velocity shears, flickering and pulsating aurora, as well as extremely sharp boundaries and gradients, often associated with narrow dark lanes and patches. These results must be applied to theoretical models if realistic estimates of the changes in energy distributions, electric fields and currents are to be explained. Combining such results with in situ spacecraft data adds information on particle distribution functions, electric fields and plasma densities, with the optical measurements giving the detailed structure and rapid evolution of events. Several examples of estimating energy and flux in different optical auroral features will be shown.

## Lee, Sungeun

### Magnetosphere – ionosphere coupling processes associated with auroral electrons using the THEMIS electron data

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We have statistically investigated electron density, temperature, thermal current, and conductivity in the plasma sheet using the data from the electrostatic analyzer (ESA) onboard the THEMIS-D satellite from Nov. 2007 to Jan. 2010. According to Knight (Planet. Space Sci., 1973) and Lyons (JGR, 1980), the thermal current, jth ($\propto n\sqrt{T}$ where n is electron density and T is electron temperature in the plasma sheet), represents the upper limit to field aligned current that can be carried by magnetospheric electrons without field-aligned potential difference. The conductivity, K ($\propto n/\sqrt{T}$), represents the efficiency of the upward field-aligned current (j) that the field-aligned potential difference (V) can produce (j=KV). Therefore, estimating jth and K in the plasma sheet is important in understanding the ability of plasma sheet electrons to carry the field-aligned current which is driven by various magnetospheric processes such as flow shear and azimuthal pressure gradient. As initial results, we found that in the dawn side inner magnetosphere, electrons can make sufficient thermal current without field-aligned potential difference, particularly during active time (AE > 100 nT), to carry typical region 2 upward field-aligned current. On the other hand, in the dusk side outer magnetosphere (source of the region 1 current), electron density and temperature are small, thus the thermal current is much smaller than the typical auroral current shown by Iijima and Potemra (JGR, 1976). From the relation (j=KV) between the typical auroral current (j) and the conductivity (K) estimated from our data, we conclude that 5-10 kV of the filed-aligned potential difference (V) is necessary on the dusk side region 1 upward field-aligned current. In the presentation we will also make comparison of the magnetospheric density and temperature measured by THEMIS in the plasma sheet with those estimated by ionospheric satellite, using several conjunction events.

## Lessard, Marc

### Recent Advances in Pulsating Aurora (*Invited*)

Lessard, Marc[1]; Rychert, Kevin[1]; Jones, Sarah[5, 1]; Donovan, Eric[2]; Spanswick, Emma[2]; Rodriguez, Juan[4]; Singer, Howard[4]; Loto'aniu, Paul[4]; Mende, Stephen[3]

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Pulsating aurora is a common phenomenon, generally believed to occur mainly in the aftermath of substorms with luminosities the order of hundreds Rayleighs to a few kR at 427.8 nm. Individual patches can span 10s to 100s of kilometers and vary greatly in shape and size, with the shape changing on a timescale of minutes. Luminosity is typically characterized by quasi-periodic brightness modulations with periods ranging from 2 to 20 seconds, and 8 seconds on average. Recent efforts at understanding pulsating aurora have focused on two aspects. First, studies using images from the THEMIS allsky array have provided a "large-scale" perspective of pulsating aurora and show that, while substorms appear to enhance pulsating aurora, pulsating aurora typically occurs across the entire post-midnight and dawn sectors, more or less continuously. These studies also show that the source region for pulsating aurora appears to evolve away from midnight and that the average duration of a pulsating aurora event (as observed by a single camera) is several hours, significantly longer than the mean interval during substorms. In addition to these efforts aimed at understanding large-scale aspects of pulsating aurora, new observations at geosynchronous orbit (above pulsating aurora events) are also presented, showing apparent particle flux oscillations with periodicities that coincide with the pulsating aurora observed on the ground. These observations, once confirmed, would provide in-situ evidence of an equatorial source for pulsating aurora.

## Li, Wen

### The Origin of the Pulsating Aurora: Modulating Whistler-Mode Chorus Waves

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Pulsating aurora, blinking on and off on a timescale of a few to tens of seconds in the upper atmosphere, is known to be driven primarily by precipitating energetic electrons (>10 keV). Investigating the origin of the pulsating aurora is an interesting but long-standing problem. Using coordinated in-situ spacecraft and ground-based all-sky imager observations from the THEMIS mission, we found that the luminosity of pulsating aurora over a single auroral patch is closely related to the modulation of the chorus wave intensity. Furthermore, almost one-to-one correlation between depletions in total plasma density and increases in chorus wave intensity was observed. We suggest that density depletions occurring in the dominant chorus source region play an important role in modulating chorus wave intensity and thus control the luminosity of the pulsating aurora. The evolution of the pulsating aurora in the ionosphere in turn provides essential information on characteristics of chorus waves in the magnetosphere, which play a significant role in controlling the dynamics of radiation belt electrons.

## Liang, Jun

### THEMIS survey of electron cyclotron harmonic waves and their association with diffuse auroras

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Electrostatic electron cyclotron harmonic (ECH) waves and electromagnetic whistler-mode chorus waves are widely recognized as the two main candidates capable of scattering the central plasma sheet (CPS) electrons into the loss cone and leading to their precipitation into the auroral ionosphere. Based upon the observations we perform an extensive survey of the magnetospheric ELF waves at radial distances L=5 to 20 RE, with particular focus on the electron cyclotron harmonic (ECH) waves. From the statistical survey we found that ECH emissions clearly intensify with enhanced magnetic activity, being most intense in the night-to-dawn sector. Moderately strong ECH waves can extend to L > ~ 12, suggesting the potential of such waves to efficiently scatter plasma sheet electrons leading to diffuse auroral precipitation. We also investigate the conjunctive auroral activities during the ECH intensification intervals for those events with favorable view condition of the THEMIS/NORSTAR all-sky-imagers (ASIs) that are conjugate to the satellites. Via a few sample events we demonstrate the excellent correlations between the ECH waves and the "patchy auroras" as well as the ambient diffuse auroras. We are particularly interested in those events when the ECH waves are observed at L>10 in the midnight sector and diffuse auroral intensifications at >67 MLAT in the ionosphere. We proposed that fast earthward flow from the mid-tail may act as a potential trigger of those higher-L-shell ECH waves and "patchy" auroras, and demonstrate that the presumably much stretched magnetic field configuration there may have significant effects on the pitch-angle scattering process.

## Lynch, Kristina

### Nightside observations of ray motion along an auroral PBI curtain: in situ and groundbased optics case study

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The Cascades2 auroral sounding rocket study provides a comparison of multipoint in situ ionospheric observations of a nightside auroral event with groundbased optical studies of the same event. Cascades2 was launched northward from Poker Flat Alaska on 20 Mar 2009 at 1104 UT. The 12 minute 43 second flight reached an apogee of 564 km over the northern coast of Alaska. The experiment array included a 5-payload suite of in situ instrumentation, ground cameras with various fields of view at three different points under the trajectory, multiple ground magnetometers, the PFISR radar at the launch site, and the THEMIS spacecraft in the magnetotail. In this presentation we detail the fine structure of the poleward boundary electron precipitation of this event and compare it to simultaneous two-point narrow-field camera observations of the resulting visible auroral structures. We discuss in particular the motions of tall rays as they move rapidly along the poleward curtain of this poleward-boundary-intensification (PBI) event.

## Lyons, Larry R.

### Relationships Between the Aurora and an Interplay of Large and Mesoscale Structure of Electrodynamical Magnetosphere-Ionosphere Coupling (*Invited*)

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Both slowly varying large-scale structure and a variety of disturbances occur within the coupled magnetosphere-ionosphere system along nightside plasma sheet field lines, and both are reflected in the aurora. Much about the large-scale structure, the more rapidly varying disturbances, and their relation to the aurora has remained poorly understood because of complicated magnetosphere-ionosphere-thermosphere coupling and limitations on capabilities for measuring and modeling the coupled system. However, this situation has started to dramatically change due to deployments of new and expanded radar systems, enhanced ground auroral imaging, multi-spacecraft of the NASA THEMIS program, and model development. First studies are now suggesting that much about the structure and disturbances may be describable and understood based on a slowly changing large-scale structure describable by Region 2 physics and its interplay with much more dynamic meso-scale structures associated with flow channels emanating from near the polar cap boundary. These new results also suggest a possible unifying view that many auroral disturbances (substorms, PBIs, streamers, and perhaps others) may be all related to the meso-scale flow channels. If so, understanding the generation and propagation of the flow channels and their coupling with the large-scale background is critical for understanding auroral disturbances, including their effects on and feedback from ionospheric and thermospheric structures. Also important will be to learn why only some PBIs (the most common disturbance) lead to streamers, why only some streamers lead to substorm onset instability within the near-Earth plasma sheet, and why some streamers lead to other disturbances. Possibilities include properties of the large-scale structure into which a streamer penetrates, and of the plasma within the streamers.

## Lystrup, Makenzie

### Jupiter's Infrared Aurora From 1995 to 2000 as Imaged by the NASA IRTF

Lystrup, Makenzie[1]

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Jupiter's H3+ infrared aurora originates in the upper atmosphere at altitudes above above the homopause, formed as a result of photo ionization of H2 and impact ionization by precipitating particles from the magnetosphere. Whereas the UV auroral emissions, which are thought to originate from lower altitudes, are a good tracer of energy inputs, the infrared aurora reflects how the atmosphere responds to those inputs. Over five years a campaign of monitoring Jupiter's infrared aurora was carried out by Connerney & Satoh, resulting in thousands of images over 51 nights, but only a very small portion of this large data set has been used in previous studies, e.g. Connerney & Satoh (1999) and Satoh & Connerney (2000). We examine this data set in order to characterize the morphology of the infrared aurora as compared with the UV aurora and to compare simultaneous observations, where available. We also aim to maximize the science output of this data set by making data products available to the community.

## Marghitu, Octav

### Auroral Arc Electrodynamics: Review and Outlook (*Invited*)

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Auroral arcs are typically described in terms of 1D stripes of increased ionospheric conductance. An upward field-aligned current (FAC) sheet above the arc is connected by a normal Pedersen current to a downward FAC sheet near the arc, while a divergence free Hall current electrojet flows along the arc. The Pedersen and Hall currents are both driven by an electric field normal to the arc, with the arc behaving as a partial Cowling channel. In contrast to this ideal model, real arcs can exhibit 2D features, the FAC can close not only normal to the arc but also along the arc via both Pedersen and Hall currents, the electric field can have a significant component along the arc. We discuss the deviations of the real arcs from the ideal 1D model, with emphasis on the arcs hosted by the Harang region - where the electric field and current transition from the evening to the morning sector favors such deviations. We also comment on the magnetosphere-ionosphere (M-I) coupling implications of the arc current closure during the substorm cycle, and on the prospects to advance the understanding of arc electrodynamics as part of the M-I system.

## Masson, Arnaud

### Cluster multi-point observations of density cavities in the Auroral Acceleration Region

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2010 marked the 10th anniversary of the ESA/NASA Cluster mission in space. During this decade, the Cluster mission has crossed a number of key regions of the Earth's magnetosphere, enabling to study the Sun-Earth connection for the first time with four point measurements. Since 2006, the orbits of the Cluster satellites are slowly evolving from a nominal polar orbit to an oblique one. Meanwhile, the perigees of their orbits are going down from 19,000 km to just a few hundred kilometres. During spring 2009 and early winter 2009/2010, Cluster scientists could make use of this natural orbital drift to target a new key region of the magnetosphere, never crossed before by multiple spacecraft: the Auroral Acceleration Region (AAR). We present new observations of density cavities captured simultaneously by multiple satellites in the AAR region. The estimation of the electron density itself will be first presented. The quantitative estimation of these cavities is of crucial importance for different physical auroral processes that will be presented. For instance, auroral kilometric radiation sources emit from plasma cavities filled by a hot and tenuous plasma. Estimation of the gradient scale of the edges of plasma cavities will also be presented.

## Mauk, Barry H.

### Auroral Current Systems at the Giant Planets (*Invited*)

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The electrical current systems that connect the broad magnetospheric enviornments of the strongly magnetized outer planets to the polar ionosphere-thermosphere regions have different configurations depending on the relative strengths of the various drivers of the system, including solar wind forcing of various types, rotational forcing, the generation of high particle pressure distributions, and internal plasma sources including satellites and planetary atmospheres. Clearly the configuration of those current systems will vary from system to system. A fundamental question is whether the relatively localized auroral processes remain invariant to the differing larger scale configurations. Here the similarities and differences between the auroral current systems at all of the giant outer planets are reviewed with a focus on how the differences influence or do not influence the more localized auroral acceleration and emission processes.

## McWilliams, Kathryn A.

### Localized Dayside Proton-Induced Auroral Emissions in the Cusp and Polar Cap

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Localized dayside far ultraviolet proton-induced emissions were identified using the SI-12 imager aboard the IMAGE satellite. The SI-12 instrument detects emissions from protons with energies greater than 1 keV. Two types of localized emissions were identified on the dayside in the polar cap region. There are localized emissions significantly poleward of the auroral oval and there are localized emissions at auroral latitudes, closer to the open-closed field boundary. These two localized emissions have distinct properties that often differ. The IMF has been shown to control both the location and the intensity of cusp aurora. The cusp aurora intensity is also controlled by both solar wind dynamic pressure and southward component of the

IMF. Cusp aurora spots are measured during both southward and northward IMF conditions; the polar cap spots, in contrast, are measured only when the IMF is northward. The radial component of the IMF also appears to play a role in the location of the polar cap spots. The location and intensity of the polar cap spots will be described in relation to upstream IMF conditions. A comparison of the locations of both the polar cap and auroral-latitude spots with SuperDARN convection patterns will be examined. Possible reconnection scenarios are presented in relation to occurrence rates, locations, and intensities of the localized polar cap spots.

## Mella, Meghan R.

### Analysis of plasma bulk properties from the Cascades-2 sounding rocket

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The sounding rocket Cascades-2 launched on 20 March 2009 from the Poker Flat Research Range at 11:04:00 UT through a series of poleward boundary intensifications (PBIs). The rocket initially crosses a diffuse arc, then crosses the equatorward extent of one PBI, and finally crosses the initiation of a separate PBI before entering the polar cap. Bulk properties of the in situ plasma data are used for comparisons between rocket payloads. Additionally, these bulk properties can be compared to the auroral light intensity from ground cameras as well as conjugate plasma measurements made at THEMIS. In the twelve minute rocket flight, we observe that the electron spectra of a PBI at its initiation is Alfvenic in nature, whereas a developed PBI (one that has had time to pull equatorward) is seemingly a mixture of an inverted-v and Alfvenic electron spectra. Altitude profiles of the light intensity taken at each of the two stages of a PBI also show that the developed PBI can be matched by a transport code using a single energy Maxwellian, whereas the initiation of the PBI is best modeled by a sum of multiple profiles. The Cascades-2 case study lends support to new ideas which state that Alfven wave dominated regions can transition to inverted-v regions [Hull et al., 2010] by providing multipoint data at rocket altitudes as opposed to Cluster altitudes. This is important for understanding how auroral PBIs develop with respect to the larger magnetospheric system.

## Mende, Stephen

### Substorm Triggering and high latitude pre-cursors

Mende, Stephen[1]; Frey, Harald U.[1]; Angelopoulos, Vassilis[2]

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Although high latitude pre-cursor phenomena of substorm onsets were thought to be an important feature of some substorm models, reports of such high latitude auroral morphology are relatively few in the literature. High latitude activity prior to substorm onset, including N-S-aligned auroral features propagating equatorward, had been reported from ground-based all sky video observations by Oguti as early as 1973 and these auroral features were seen to make contact with the substorm break up arc immediately prior to onset. These “contact break up” auroral onsets were frequently seen and were located within the region of simultaneously observed proton precipitation, providing evidence that substorm onsets occur on field lines where energetic protons are trapped. The pre-break up equatorward moving, high latitude auroral features should map to earthward flowing plasma structures in the magnetotail and they have been associated with short duration pulsed plasma flows or bursty bulk flows. For instance experimental evidence from the Viking satellite imager showed a relationship between north-south aligned auroral forms and bursty bulk flows in the mid-tail. Most of these flow associated auroral features were not seen before but after substorm onset and during substorm expansion and recovery phases. The THEMIS satellites and associated ground-based observatories have sufficiently large latitude and local time coverage, high spatial resolution and time cadence to permit more definitive simultaneous observations of the substorm aurora. Nishimura et al. [2010] reported that a distinct, repeatable sequence of substorm intensification is often seen starting with poleward boundary intensification (PBI) typically away from the meridian of the subsequent pseudo-breakup, substorm re-intensification or onset. Apart from a few, most reported cases were substorm re-intensifications. It is still plausible to assume that the same mechanism leading to substorm re-intensifications and subsequent poleward expansion is also responsible for substorm energy release in isolated substorms. The described repeatable sequence gives strong evidence that mid-tail plasma processes act as substorm onset triggers in many cases. However, the presence of precipitating protons still shows that the initial energy release associated with the substorm expansion occurs relatively close to the earth in the region of closed field lines.

## Michell, Robert G.

### Dispersion Analysis of Flickering Aurora

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We present observations of a flickering aurora event that was observed on 23 October 2009 from Poker Flat Alaska. The data were recorded using the PFISR Andor EMCCD narrow field of view (15 x 15 degrees) imager, operated by the University of Alaska, Fairbanks. The images were recorded at 33.58 frames per second resulting in 256 x 256 pixel images. The specific event analyzed consists of a time series of images lasting approximately 30 seconds (1000 images) where active flickering aurora was observed throughout the entire sequence. An asymmetry was found in the scale size of the patches, with the North-South direction extending to smaller scales (1050 m) than the East-West direction (1570 m). The calculation of the dispersion relation (omega vs. k), reveals that the temporal frequencies of the luminosity variations occur throughout the well-defined range of 5 to 14 Hz, with the peak power at approximately 10 Hz. Computing such relations for flickering aurora will enable direct comparisons between observation and theory.

## Milan, Stephen E.

### Auroral and Ionospheric Evolution During Substorms and Ramifications for the Earth's Magnetotail

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We describe the general characteristics of the evolution of the auroral, ionospheric, and magnetotail signatures of magnetospheric substorms. We present results of superposed epoch analyses of 2000 substorms, identified by Frey et al. (2004), of Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) auroral images, Super Dual Auroral Radar Network (SuperDARN) ionospheric flows, and other measures of magnetospheric disturbance. In particular we examine the effect of the onset latitude and onset MLT on the subsequent evolution of the substorms. The results are interpreted within the expanding/contracting polar cap paradigm (ECPC), and the ramifications for magnetotail structure and dynamics are discussed.

## Miyoshi, Yoshizumi

### Fine structures of precipitating electrons associated with pulsating aurora: Reimei observations

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We present results of fine structures of precipitating electrons as seen in energy-time diagrams associated with pulsating aurora from the Reimei observations. Reimei often observes electron precipitations at two different energy ranges. Higher energy electron precipitations more than a few keV are observed, which mainly drives the pulsating aurora, while lower energy precipitations around 1 keV are relatively stable. The precipitation energy increases gradually when the satellite moves from the higher to the lower latitude, suggesting that the cyclotron resonance works for the precipitation of electrons. There is a clear precipitation gap between higher and lower energy precipitations. In order to investigate possible wave modes that cause the observed fine structures of such precipitations, we calculate the scattering rate of precipitating electrons using the model wave spectrum. From the calculations, it is found that the upper (lower)-band chorus causes the observed lower (higher)-energy precipitations. The precipitation gap between lower and higher energy precipitations corresponds to the frequency gap at half gyro-frequency that is usually seen at whistler mode chorus waves. Therefore, it is suggested that the fine structures of precipitating electrons associated with the pulsating aurora can be caused by whistler mode chorus wave-particle interactions near the magnetic equator.

## Morioka, Akira

### Two-step evolution of auroral acceleration and substorm onset

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The evolution of field-aligned acceleration is shown in connection with auroral substorm onset on the basis of AKR source dynamics. Our investigations revealed that the auroral-acceleration process basically consists of two steps. The first is the appearance/intensification of low-altitude acceleration at an altitude of 4000-5000 km that induces initial brightening. The second step is the breakout of high-altitude field-aligned acceleration (6000-12,000 km) above pre-existing low-altitude acceleration, which results in violent auroral breakup and poleward expansion. Low-altitude acceleration which is not followed by the breakout of high-altitude acceleration (one-step evolution) is a pseudo-substorm. Plasma-flow bursts in the CPS were investigated in connection with the evolution of field-aligned acceleration in the M-I coupling region. About 65 % of the flow bursts were related to field-aligned acceleration in the M-I coupling region and one third of them developed to full-substorm, while the magnitude of the flow velocity did not necessarily divide between the pseudo- and full-substorm. It is also shown that flow bursts composed of higher β plasma made it somewhat harder to affect the M-I coupling region. We proposed substorm-onset scenario where an earthward flow burst generated by mid-tail reconnection causes the first-step evolution of substorms (low-altitude acceleration) and the subsequent instability driven by enhanced FAC in the M-I coupling region ignites substorm breakup.

## Motoba, Tetsuo

### Varying IMF By effects on interhemispheric conjugate auroral features during a weak substorm

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Interhemispheric conjugate auroral features during a weak substorm on September 21,2009, were investigated using simultaneous all-sky camera (ASC) measurements at the northern and southern geomagnetic conjugate points: Tjornes (TJO, 66.2N, 342.9E) in Iceland and Syowa Station (SYO, 69.0S, 39.6E) in Antarctica. The time sequence of the interhemispheric conjugate auroral features was well reflected in the geomagnetic field variations at both stations. Based on a detailed comparison of both ASC images, we identified that the northern geomagnetic footprint of SYO was displaced poleward of TJO by up to 3.0 deg or more in the initial stage of substorm development, whereas in the late stage it was displaced eastward by up to ~1h relative to TJO and then it moved closer to TJO. In addition, we analyzed the magnetic field data observed at four Cluster satellites in the 11-14 RE near-Earth tail, in close conjunction with the TJO-SYO conjugate optical auroras. Interestingly, we found that the variations in the magnetic field y-component (By) at all satellites correlated moderately well with the variations in the time-shifted IMF clock angle. Simultaneous ground and satellite observations allow us to conclude that the dynamic motion of the conjugate points are a consequence of the time-dependent magnetotail field reconfiguration (twisting) process, controlled by the varying IMF By polarity.

## Mottez, Fabrice

### Quasi-static electric structures formed through Alfvén waves interaction

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Several observations show that the regions of auroral alfvénic acceleration become later regions of acceleration by quasi-static electric structures, such as strong double layers. It has been suggested that the quasi-stationary electric fields could be caused by the interaction of downgoing and upgoing Alfvén waves. This question is investigated through a series of numerical simulation. We show that Alfvén waves interaction can effectively trigger parallel electric fields, and localized particle acceleration. The properties of this phenomena are investigated through a parametric study.

## Mutel, Robert L.

### The Connection between Discrete Auroral Arcs and AKR: Evidence from Polar and Cluster Observations in the Acceleration Region

Mutel, Robert L.[1]; Menietti, Doug[1]; Christopher, Ivar[1]; Pickett, Jolene[1]; Gurnett, Donald[1]; Sigwarth, John[2]

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Both Polar and Cluster spacecraft observations of auroral kilometric radiation (AKR) dynamic spectra occasionally show distinctive V-shaped profiles when the spacecraft traverse the Earth's auroral acceleration regions. For the Polar observations, we have used simultaneous optical images of the auroral oval at the source foot points to show a strong correlation of the AKR signature with discrete auroral features. We discuss several examples of V-shaped AKR profiles for which the time of nadir passage (bottom of V) coincides with the spacecraft crossing field lines connected to bright discrete optical auroral arcs. We have reproduced the V-shaped dynamical spectra by modeling the AKR source emission region as a thin sheet with footprint on the discrete arc and beamed discrete uniformly populating the sheet. The Cluster observations, taken when the spacecraft were in the sheath or boundary layer of an auroral cavity, allow a detailed probe of propagation for both X-mode and Z-mode AKR in cavity walls. These results support models of AKR emission populating thin density cavities with radiation initially confined to a 'tangent plane' but strongly refracted upward as they propagate through the cavity boundary layer. The inferred spatial distributions of AKR sources are closely coincident with field lines connecting discrete auroral arcs, indicating that discrete arcs are highly correlated with robust AKR emission on the same field lines, as first suggested by Gurnett (1974) several decades ago.

## Nagai, Tsugunobu

### Linkage of magnetic reconnection in the magnetotail to substorm onset on the ground

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Geotail observations in the magnetotail are combined with IMAGE ground magnetometer network observations to demonstrate that magnetic reconnection in the mid-tail is linked with substorm onset on the ground. The substorm onset location on the ground is determined as the center of the westward electrojet calculated with the ionospheric equivalent current technique. Geotail provides in situ observations of magnetic reconnection in the magnetotail at radial distances of 10-32 Re. For the westward electrojet development for substorm onset at lower latitudes on the ground, magnetic reconnection tends to take place close to the Earth, typically inside 20 Re. For the westward electrojet development for substorm onset at higher latitudes, magnetic reconnection tends to take place relatively far from the Earth, typically beyond 20 Re. For a multiple onset substorm, the location of each westward electrojet tends to shift toward higher latitudes on the ground. Geotail, which can stay at the same position in the magnetotail during a series of onsets, observes tailward flows with negative Bz, flow-reversal from tailward to earthward, and then earthward flows. These observations indicate that magnetic reconnection in the mid-tail is directly coupled with the substorm onset on the ground, probably with field-aligned currents consisting the Hall current system of magnetic reconnection.

## Nakamizo, Aoi

### Energy conversion process in the near-earth plasma sheet during substorms deduced from data analysis and MHD simulation

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The magnetospheric substorm is the fundamental but the unsolved problem in the solar-terrestrial physics. In particular, the generation process of substorm-FAC, the heart of the substorm dynamics, is not fully discussed and understood in the context of the momentum/energy balance in the Magnetosphere-Ionosphere coupling system. Based on the analysis of GOTAIL/MGF, LEP and EPIC data, we have suggested that MHD slow mode is the primary process as a non-Alfvénic (non-convective) motion in the earth's magnetotail. Based on the slow mode interpretation, a scenario for the generation mechanism of substorm-FAC is proposed. However, we have not fully explained details, including the momentum/energy conversion at the site of plasma sheet and the stress/energy matching between the magnetosphere and ionosphere. In this study, we examine these details by comparing data analysis and MHD simulation, focusing on the plasma pressure changes and flow patterns.

## Ng, Chung-Sang

### Electrostatic Structures in Space Plasmas: Studies of Two-dimensional Magnetic Bernstein-Greene-Kruskal Modes

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Electrostatic structures have been observed in many regions of space plasmas, including the auroral acceleration region. One possible description of some of these structures is relating them to Bernstein-Greene-Kruskal (BGK) modes, which are exact solutions of the Vlasov equation. While there have been approximate solutions of higher dimensional BGK modes, a three-dimensional (3D) BGK mode in a finite

magnetic field has not been constructed yet. We present here new studies of 2D BGK modes in a magnetized plasma with finite magnetic field strength in order to gain insights of the ultimate 3D theory. The original method of constructing these modes was presented in [Ng, Bhattacharjee, and Skiff, Phys. Plasmas 13, 055903 (2006)], which showed that these modes satisfy the exact electromagnetic Vlasov-Poisson-Ampere system. Exact solutions using a new method, as well as results on simulating these modes using Particle-in-Cell (PIC) simulations, which are important in studying the stability of these modes, will be presented. This work is supported by a National Science Foundation grant PHY-1004357.

## Nishimura, Yukitoshi

### Pre-onset time sequence of auroral substorms

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A critical, long-standing problem in substorm research is identification of the sequence of events leading to substorm auroral onset. Based on event and statistical analysis of THEMIS all-sky imager data, we have shown that there is a distinct and repeatable sequence of events that is initiated by a poleward boundary intensification (PBI) followed by a north-south (N-S) arc moving equatorward towards the onset latitude leading to substorm auroral onset. We have now investigated differences between N-S arc sequences that do and do not lead to substorm expansion onset. We found that the two types of N-S arcs have similar characteristics. There is, however, one difference between the sequences of N-S arc evolution. Each N-S arc leads to small intensification of the growth phase arc, and when the onset-related N-S arc reaches the equatorward portion of the auroral oval, the pre-existing growth phase arc is much brighter than at the times of non-onset related N-S arcs. The onset arc is typically a thin arc near the poleward boundary diffuse growth-phase arc. Assuming that the growth-phase arc is related to enhanced pressures at the inner edge of the plasma sheet, this difference indicates that the near-Earth plasma pressure distribution at the time of plasma sheet fast flows is crucial in substorm triggering. These observations suggest that substorm onset instability is possible only when the pre-existing inner plasma sheet pressure is sufficiently large.

## Nishiyama, Takanori

### The source region and its characteristic of pulsating aurora based on the Reimei observations

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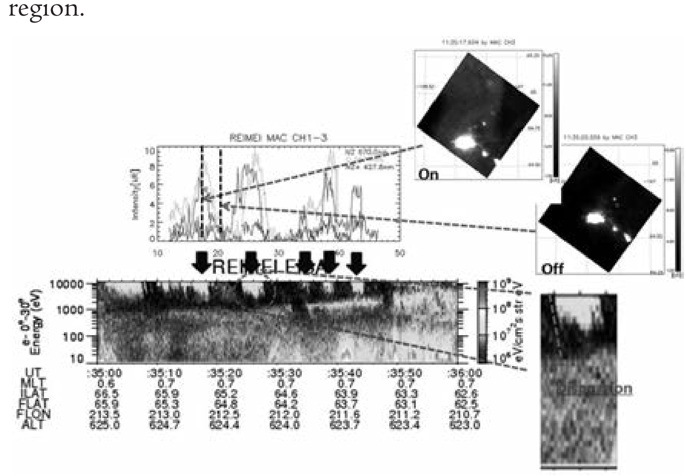
5. Graduate School of Science, University of Tokyo, Sagamihara, Japan

Using image and particle datasets obtained from observations by the Reimei satellite, we carried out Time-of-flight (TOF) analysis for 29 pulsating aurora events to understand the precise properties of pulsating auroras and the possible generation process. While the sources identified using a standard TOF model were distributed almost continuously from magnetic latitudes 50° to –20°, the sources identified using a different TOF model that takes into account whistler wave propagation were confined to the equatorial region up to about 15°. The latter source distribution agrees with previous statistical studies of whistler mode chorus waves. In addition, the cold plasma density of the source region and the wave frequency can be estimated from the latter TOF analysis. The estimated cold plasma density and wave frequency normalized by the equatorial cyclotron frequency were 0.20 – 21.7 cm$^{-3}$ and 0.22 – 0.65, respectively. Moreover, the estimated wave frequency clearly depended on the invariant latitudes of the pulsating aurora source region, and the frequency increased as the distance from the Earth decreased (up to about 5 – 6 $R_E$), corresponding to the frequency range of the upper band chorus. These results suggest that different types of chorus wave bands contribute the electron scattering of pulsating auroras, which depends on the radial distance of the source region.




Summary plots of simultaneous image-particle observation by the Reimei satellite

## Ostgaard, Nikolai

### Auroral asymmetries in the conjugate hemispheres during substorm onset and expansion phase (*Invited*)

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Simultaneous global imaging in the ultraviolet wavelengths by the IMAGE and Polar satellites are used to examine the dynamics of the auroral substorm. When mapped onto apex coordinates, the auroral features in the conjugate hemispheres are usually found to be asymmetric. Earlier studies have demonstrated that the asymmetries of substorm onset locations in the two hemispheres are controlled by the IMF. We will show how both the IMF clock angle or IMF By can be used to organize the substorm location, and how they give slightly different information. We will also show results from following similar features in the two hemispheres during expansion phase of two substorms. We find that the asymmetry induced by the IMF clock angle at substorm onset disappear during the expansion phase implying that magnetic field lines with asymmetric footpoints are rectified during expansion phase. Various mechanism that can re-establish the symmetric aurora are discussed.

## Otto, Antonius

### Entropy Constraints and Current Sheet Thinning During the Substorm Growth Phase

Otto, Antonius[1]; Hall IV, Fred[1]

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Invariants are particularly important to model, diagnose, and generally better understand physical processes. Particularly entropy is an interesting quantity for the state and dynamics of the magnetosphere. The integral flux tube entropy characterizes stability and provides an important constraint for convection in the magnetosphere. It may also serve to identify non-adiabatic processes that participate in the entry of plasma from the magnetosheath into the magnetosphere. Here we will discuss the evolution of the magnetotail as a result of dayside reconnection. Observations indicate that the net flux transport due to azimuthal convection balances the dayside reconnection rate after about 15 to 20 minutes after the IMF turns southward which implies the depletion of closed magnetic flux from the plasma sheet. We have postulated that subject to the constraint of entropy conservation this may lead to the thinning of the tail current sheet because of the removal of magnetic flux in the near Earth plasma sheet. The process is studied using three-dimensional mesoscale simulations which impose the azimuthal convection toward the dayside as a boundary condition. The simulations illustrate that these boundary conditions lead to strong current sheet thinning where the thinning process accelerates toward the end of the growth phase similarly to corresponding observations. We examine properties of the process such as location, duration, and structure of the current sheet thinning.

## Ozak, Nataly

### Atmospheric Effects of Auroral Ion Precipitation at Jupiter

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Auroral emissions from Jupiter have been observed across the photon spectrum including ultraviolet and X-ray wavelengths. X-ray emissions with a total power of about 1 GW were observed by the Einstein Observatory, the Roentgen satellite, Chandra X-ray Observatory (CXO), and XMM-Newton. Previous theoretical studies [Cravens et al. 1995, Kharchenko et al. 1998, Liu and Schultz 1999, Kharchenko et al. 2006, 2008, Hui et al. 2009, 2010, and Ozak et al. 2010] have shown that precipitating energetic sulfur and oxygen ions can produce the observed X-rays. This study presents the results of a hybrid Monte Carlo model for sulfur and oxygen ion precipitation at high latitudes, looks at differences with the continuous slowdown model, and compares the results to synthetic spectra fitted to observations. We concentrate on the effects of altitude on the observed spectrum. The opacity of the atmosphere to the outgoing X-ray photons is found to be important for incident ion energies greater than about 1.2 MeV per nucleon for both sulfur and oxygen. Model spectra are calculated for intensities with and without any opacity effects. These synthetic spectra were compared with results shown by Hui et al. [2010] which fit CXO observations for the north and south Jovian auroral emissions. Quenching of longer-lived excited states of the oxygen ions is found to be important. Opacity considerably diminishes the outgoing X-ray intensity calculated, particularly when the viewing geometry is not favorable. Secondary electrons from the ion precipitation as well as photoelectrons also affect the polar cap atmosphere. Electron fluxes for both populations are also analyzed and field aligned electrical currents as well as temperature profiles are estimated for the polar cap region.

## Pilipenko, Viacheslav

### Dispersion relationship for the ballooning mode and instability criteria

Pilipenko, Viacheslav[1, 2]; Fedorov, Evgeny[2]; Engebretson, Mark J.[1]

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As a possible trigger of the substorm onset, the ballooning instability - a localized expansion of plasma "bubble", has been often suggested. The ballooning disturbances in a finite-pressure plasma immersed into a curved magnetic field are described with the system of coupled equations for the Alfven and slow magnetosonic modes. Commonly these disturbances are characterized by the local dispersion equation which is widely applied for the description of ULF oscillatory disturbances and instabilities in the nightside magnetosphere. However, the exact form of this equation is somewhat different among different authors. We have reduced the basic system of equations in a mathematically strict way to the dispersion equation for the small-scale in transverse direction disturbances. As a result, we have derived a mathematically correct relationship which can be used for geophysical applications. In particular, from this relationship the modification of the ballooning instability threshold derived in previous papers is obtained.

## Pitkänen, T.

### EISCAT-Cluster observations of quiet-time near-Earth magnetotail fast flows and their signatures in the ionosphere

Pitkänen, T.[1]; Aikio, A. T.[1]; Amm, O.[2]; Kauristie, K.[2]; Nilsson, H.[3]; Kaila, K. U.[1]

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2. Finnish Meteorological Institute, Helsinki, Finland
3. Swedish Institute of Space Physics, Kiruna, Sweden

We discuss observations of a sequence of quiet-time Earthward bursty bulk flows (BBFs) measured by the Cluster spacecraft in the near-tail plasma sheet ($X_{GSM}$ −12 to −14 $R_E$ ) in the evening sector, and by simultaneous high-resolution measurements in the northern conjugate ionosphere by the EISCAT radars, a MIRACLE all-sky camera and magnetometers, as well as a meridian-scanning photometer (MSP) on 17 October 2005. The BBFs at Cluster show signatures that are consistent with the plasma "bubble" model. In addition, clear signatures of tailward return flows around the edges of the bubble can be identified. The duskside return flows are associated with significant decrease in plasma density, giving support to the recent suggestions of formation of a depleted wake. However, the same feature is not seen for the dawnside return flows, but rather an increase in density. In the ionosphere, EISCAT and optical measurements show that each of the studied BBFs is associated with an auroral streamer. Within the streamer itself and poleward of it, the ionospheric plasma flow has an equatorward component, which is the ionospheric manifestation of the Earthward BBF channel. A sharp velocity shear appears at the equatorward edge of a streamer. We suggest that each BBF creates a local Harang -type plasma flow pattern in the ionosphere, in which the plasma flow poleward of and inside the streamer is in the direction of the streamer and southeastward. A northwestward return flow is located on the equatorward side. The EISCAT data show that the return flow is associated with low ionospheric plasma density, in agreement with decreased densities measured by Cluster. In summary, we present the first simultaneous observations of BBF proper and return flows both in the plasma sheet and in the ionosphere, and those are in accordance with the bubble model.

## Pottelette, Raymond

### Nonlinear structures driven by tail reconnection processes in the Alfvénic region

Pottelette, Raymond[1]

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Hall currents -generated in the tail reconnection sites during substorms- are not divergence free and their closure can only be provided by field-aligned currents. We use high time resolution data from the FAST spacecraft and we concentrate on the so-called Alfvénic region which is magnetically linked to the nightside Polar Cap boundary. This region consists of recently reconnected field lines. As expected, the signature of such reconnection processes evidenced in the auroral ionosphere, consists in one pair of closely separated downward-upward field-aligned currents. Strong turbulent fluctuations are detected in association with the field aligned currents. The low frequency component (~ 1 Hz) of the electric field fluctuations consists of localized structures whose characteristics are not entirely consistent with the presence of Alfvén waves. They may represent a possible example of the coupling of Alfvén waves with electron acoustic waves on small length scales. In the high frequency range (~1 kHz), the turbulent fluctuations are dominated by large amplitude (~ 500 mV/m) bipolar electric field structures whose polarity depends on the direction of the field aligned currents. These structures are moving earthward in the upward current region and anti-earthward in the downward current region. The observations provide evidence that the Hall current system, generated in the ion diffusion region of a distant tail reconnection site, can close in the ionosphere. The generation of both low- and high-frequency nonlinear structures appears as a natural consequence of the disturbances imposed on the Alfvénic region during substorms when hot and cold plasmas interact.

## Raeder, Joachim

### OpenGGCM Simulation of a Substorm: Axial Tail Instability and Ballooning Mode Preceding Substorm Onset

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3. Center for Space Physics, Boston University, Boston, MA, USA

It is generally accepted that magnetic reconnection is the main mechanism that dissipates power during a substorm. It is less clear, however, whether the beginning of magnetic reconnection in the magnetotail also signifies the onset of the substorm expansion phase itself, i.e., whether the "outside-in" scenario applies, or if a different process happens first closer to Earth that triggers the reconnection onset in the magnetotail, i.e., the "inside-out" scenario. Global MHD simulations have generally supported the "outside-in" scenario. However, ideal MHD instabilities that could possibly trigger tail reconnection may have been missed due to coarse numerical resolution or due to other numerical effects. Here, we present results from an OpenGGCM simulation of the March 23, 2007 substorm that clearly shows growth of the ballooning mode as suggested by our earlier analysis (Zhu et al., 2009), as well as growth of an ideal-like instability that is purely axial and was previously reported by Siscoe et al. (2009). Both instabilities occur simultaneously and are immediately followed by reconnection onset. The simulations results are in accordance with recent Geotail observations of ballooning with a wavelength of approximately 0.5 RE, and the time scales agree with that of the explosive growth phase. The exact relation between the three instabilities, i.e., ballooning, the axial mode, and tearing, is not entirely clear yet; however, having demonstrated that the OpenGGCM reproduces all of them, they can now be analyzed in more detail. In particular, we present the expected auroral signature of these processes, which will allow for a more detailed comparison of the simulation results with ground based imagers.

## Raeder, Joachim

### Global MHD Modeling of Pre-Onset PBI Events

Zhu, Ping[1]; Raeder, Joachim[2]

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2. Space Science Center, University of New Hampshire, Durham, NH, USA

The Feb 29 2008 pre-onset poleward boundary intensification (PBI) event has been modeled using ACE solar wind data and OpenGGCM simulations. The ionosphere discrete electron precipitation patterns from simulation qualitatively resemble those of the pre-onset PBI in ASI data. Initial comparison with the observation data suggests that the equatorward intrusion of the pre-onset PBIs alone may not be sufficient in triggering the substorm onset process in the near-Earth magnetotail. Analysis of the simulation results indicates that local minimum developed in tail entropy profile in the poleward boundary and moved Earthward when approaching onset. These structures are (marginally) interchange unstable. The mapping and correlation between the development of the local minimum entropy region in tail and the PBI-like patterns in ionosphere will be discussed.

## Rankin, Robert

### Pc5 Field Line Resonances: Theory and Observations (*Invited*)

Rankin, Robert[1]; Kabin, Konstantin[1]; Watt, Clare E.[1]; Sydorenko, Dmytro[1]

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There is a clear link between Pc5 pulsations and certain aspects of auroral precipitation in the 100's of eV to 1keV range. The evidence comes from ground -based magnetometer, meridian scanning photometer and all-sky camera observations of discrete arcs. It is quite common to observe modulations of discrete arcs at periods ranging from a few minutes up to 10 minutes or so. The large parallel wavelength of Pc5 field line resonances (FLRs) implies that parallel electric fields in the waves should be small, on the order of micro-volts per meter according to two-fluid MHD theory. On the other hand, electron dynamics in FLRs at long wave periods is non-local and outside the validity of two fluid theory. Attempts have been made to include effects of wave-particle interactions in two-fluid MHD by postulating turbulent or anomalous resistivity at low altitude. This can perhaps explain some or all of the observed precipitation, but models that account for self-consistent kinetic processes in Pc5 waves are ultimately needed. In this talk, we review the state of the art in modeling Pc5 waves, and by appealing to both THEMIS and ground-based observations, attempt to summarize what models tell us so far about kinetic scale physics in FLR's. We will attempt to summarize what we know, and where remaining gaps exist in the theory.

## Ray, Licia C.

### Auroral Signatures of Ionosphere-Magnetosphere Coupling at Jupiter and Saturn (*Invited*)

Ray, Licia C.[1]

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Jupiter and Saturn exhibit dynamic auroral processes which are signatures of the coupling between the planetary atmosphere and magnetosphere. The two regions are coupled by field-aligned currents which transfer angular momentum between the planet and the magnetospheric plasma. As the field-aligned currents grow, field-aligned

potentials develop accelerating electrons into the planetary atmosphere and modifying the auroral ionosphere. I will review how auroral energy inputs have traditionally been treated in magnetosphere-ionosphere coupling models at the giant planets, primarily through modification of the ionospheric Pedersen conductance, and how this feedback affects the auroral current system and our understanding of the physical processes driving auroral emissions at Jupiter and Saturn.

## Redmon, Robert J.

### A global view of O+ upward flows and outflow rates between DMSP and POLAR


Redmon, Robert J.[1]; Peterson, William[2]; Andersson, Laila[2]; William, Denig[1]

1. Solar Terrestrial Physics, NOAA, Boulder, CO, USA
2. LASP, Boulder, CO, USA



Contemporary environmental modelers now include particle species dependent dynamics in magnetospheric specifications. Energetic O+ has significant consequences for the stored energy contained within the ring current and, perhaps, the timing of substorm injections. The mechanism by which thermal O+ escapes from the top of the ionosphere and into the magnetosphere is not fully understood. Previous work has indicated there is a MLT dependence on the energization efficiency of thermal ions between DMSP altitudes (~840 km) and Polar altitudes (6000-9000 km). The study was inconclusive due to the uncertainties associated with dynamic expansions and contractions of the auroral oval. These prior results support the need to project upward bulk O+ flows at DMSP altitudes into dynamic auroral boundary oriented coordinates in order to compare with measurements at altitudes above DMSP. In this paper, we present an auroral boundary corrected global comparison of O+ upward flows to escaping outflows and consider various energization mechanisms.


## Sadler, Brent

### Auroral Precipitation as a Driver of Neutral Upwelling in the Cusp


Sadler, Brent[1]; Otto, Antonius[2]; Lessard, Marc[1]; Lund, Eric[1]; Luhr, Hermann[3]

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2. Geophysical Inst, University of Alaska, Fairbanks, AK, USA
3. GeoForschungsZentrum, Potsdam, Germany



Recent observations have confirmed neutral particle upwelling at high latitudes which are localized to the polar cusp region. The small-scale density structures associated this upwelling are consistently correlated with strong small-scale field-aligned currents and are often associated with soft electron precipitation similar to that which drives night-side aurora ("auroral precipitation"). We investigate this issue with a numerical model originally developed to study dynamics associated with precipitation of tall auroral rays. The model incorporates detailed electron, ion and neutral dynamics to study various processes (e.g., heating, ion outflow, auroral luminosity) in a general sense: no mechanism is explicitly included to accelerate particles upward. Field and particle data from FAST and accelerometer data from CHAMP from a single favorable conjunction alignment event are input to the model. Results are given which support auroral precipitation as a driver to the density enhancement for this event. This mechanism requires a "cooking time" of 10 to 30 minutes before the density enhancement achieves steady state. Model results are compared with measured data from CHAMP for the event. Auroral images from the Polar satellite are used to further evaluate the model's results.


## Saita, Satoko

### Displacement of geomagnetic conjugate points due to substorm-related changes in the near-Earth magnetotail field structure


Saita, Satoko[1]; Kadokura, Akira[2]; Sato, Natsuo[2]; Fujita, Shigeru[3]; Tanaka, Takashi[4]; Ebihara, Yusuke[5]; Ohtani, Shin[6]; Ueno, Genta[7]; Murata, Kenji[8]; Matsuoka, Daisuke[9]; Higuchi, Tomoyuki[7]

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2. National Institute of Polar Research, Tachikawa, Japan
3. Meteorological College, Chiba, Japan
4. Kyushu University, Fukuoka, Japan
5. Institute for Advanced Research, Nagoya University, Nagoya, Japan
6. Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA
7. The Institute of Statistical Mathematics, Tachikawa, Japan
8. National Institute of Information and Communications Technology, Kokubunji, Japan
9. Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan



It is generally considered that auroral particles guided along geomagnetic field lines fall into the Earth's atmosphere. Thus we can expect that nightside auroras appear simultaneously at both footprints of the field lines. However, auroras do not always simultaneously appear at the geomagnetic conjugate points. There are some possible explanations for asymmetric (non-conjugate) auroras. We can divide them into two categories. The first category is relative displacements of the geomagnetic conjugate points. The second category is north–south asymmetry of the acceleration conditions in the magnetosphere. To investigate the relative displacements of the geomagnetic conjugate points, we trace both footprints of the geomagnetic field lines during the magnetospheric reconfiguration. The empirical models are insufficient for reproducing the local and transitional magnetospheric configuration changes during a substorm. In this study, we reproduce the magnetospheric reconfiguration under a southward and

duskward interplanetary magnetic field (IMF) condition by a numerical magnetohydrodynamics (MHD) simulation. Several substorm-like features, namely the formation of a near Earth neutral line, fast Earthward flow and tailward release of the plasmoid, occur about 1 hour after a southward turning of the IMF. The surveyed field line traced from the near-Earth magnetotail was strongly distorted toward dusk in the north and toward dawn in the south after the `substorm' onset. The maximum of the relative displacement of both footprints is 4.5 in MLT (magnetic local time) in the geomagnetic longitude. While observational studies have indicated that the IMF orientation is the main controlling factor of the relative displacement of the conjugate points, this simulation study with constant IMF orientation shows for the first time that the substorm-related changes in the magnetic field and the field aligned current (FAC) are likely to be major controlling factors of the relative displacement of conjugate points.

## Saka, Osuke

### Activation of auroras at the poleward edge by bifurcated fast plasma flows

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2. University of Tokyo, Tokyo, Japan

The substorm current wedge has recently interpreted by inflation of inner magnetosphere by weakening of cross-tail current, and is reportedly preceded by transitional intervals of about 10 min characterized by earthward flow and bifurcation (Saka et al., JASTP 2010). This paper reviews the evidence of auroral activations by the shear flow. We used magnetic field data at geosynchronous altitudes and all-sky image at conjugate ground station. We made the following observations: (1) Compressional pulse propagated westward (eastward) beyond L=6.6Re. (2) The pulse generated CW (CCW) polarizations in the equatorial plane. (3) Auroral surge activated at poleward edge during the pulse passage. (4) Magnetic pulse and auroral surge propagate westward (eastward) at the angular velocities of 0.2~1.0 deg/s. Based upon these observations, we conclude that: (1) Substorm injections generate shear flow burst beyond L=6.6Re. (2) Assuming the shear flow is the Alfvenic burst, poynting fluxes and field polarizations are consistent with Alfvenic spikes observed at plasma sheet-lobe boundary by the Polar satellite (Wygant et al., JGR 2000). (3) Auroral surge in poleward edge is activated along the shear flow by the Alfvenic accelerations.

## Sakaguchi, Kaori

### Ion cyclotron waves and co-rotating isolated proton auroras

Sakaguchi, Kaori[1]; Shiokawa, Kazuo[2]; Miyoshi, Yoshizumi[2]; Connors, Martin[3]

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3. Athabasca University, Athabasca, AB, Canada

Proton auroras are produced by neutral hydrogen that in turn is created when incident auroral protons from the magnetosphere pick up electrons in charge exchange collisions. The main cause of proton precipitation is pitch angle scattering in the region of the stretched magnetic field in the magnetosphere where the scale of the magnetic curvature radius is comparable to, or smaller than, the proton gyroradius. This means proton aurora is an ionospheric indicator of the transition region between highly-stretched and less-stretched magnetic-filed configuration in the magnetosphere. In the inner magnetosphere, proton precipitation is sometimes caused by resonant scattering with electromagnetic ion cyclotron (EMIC) waves, and produces 'isolated proton aurora' at subauroral latitudes with localized features [Sakaguchi et al., 2007,2008]. The EMIC waves grow in the anisotropic hot ion distribution in the ring current, and the growth rate is largely controlled by ambient plasma density, ion composition and field intensity. Thus, isolated proton aurora is a ionospheric indicator of wave-particle interaction between protons and ion cyclotron waves in the inner magnetosphere. In this presentation, we show an event of isolated proton aurora observed in the post-midnight sector on October 18, 2006 at Athabasca after substorm activity. The isolated proton aurora expanded only eastward and not westward. From the observation of 630.0-nm emission, a SAR arc, which is an indicator of the plasmapause, was found to exist 2 hours before the isolated arc appearance. The isolated proton aurora started to brighten along the SAR arc, associated with the enhancement of the geomagnetic pulsations in the frequency range of EMIC waves. The NOAA satellite identified trapped and precipitating ion (30-250 keV) enhancements causing the isolated proton auroras at subauroral latitudes. We found that the subauroral ion fluxes drifted eastward with a speed close to the Earth's rotation until it reached the post-noon sector using sequential passes of four NOAA satellites. However, energetic ions cannot drift eastward in Earth's dipole fields. From these observations, we conclude that EMIC waves generated along with the plasmapause can be confined within cold plasma structures, and proton auroras and precipitations are observed apparently drifting eastward with the speed of the co-rotation.

## Sakanoi, Takeshi

### Fine-scale black aurora and its generation process using Reimei image-particle data (*Invited*)

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6. Univ. of Tokyo, Tokyo, Japan

We focus on black aurora defined as small-scale black features seen in uniform diffuse aurora. Past measurement data showed that the black aurora is probably caused in association with the suppression of pitch-angle scattering. However, its characteristics such as stability, shape (arc, dots, etc) and dynamics, and the generation process of the suppression of pitch-angle scattering are not understood well. After the successful launch in 2005, Reimei still continues auroral measurements at 650-km altitude in the post midnight sector. MAC measures N2+ 1N (427.8 nm), OI (557.7 nm) and N2 1P (670 nm) simultaneously with spatial and time resolutions of 1 km and 120 ms, respectively. ESA and ISA measure electrons and ions, respectively, in the energy range of 10 – 12000 eV/q with time (spatial) resolution of 40 ms (300 m), respectively, although ESA was failed at August in 2008. From comparison between auroral image and particle data, we find the clear latitudinal relationship between black aurora and pulsating aurora: Black aurora always appears in the region poleward of pulsating aurora, and the boundary between black and pulsating aurora corresponds to the equatorward edge of ion plasmasheet. Interestingly, the black aurora is often accompanied by an inverted-V with typical peak energy of a few keV where we see the equatorward edge of ion plasmasheet as mentioned above. The inverted-V seems to play important roles as follows. (1) The inverted-V produces the region-2 upward field-aligned current in the post midnight sector. (2) The inverted-V convergent potential structure produces the ExB drift motion of black aurora on the ionosphere. (3) It is suggested that ion beam is generated due to the inverted-V potential, and the existence of ion beam might affect the pitch-angle scattering process that is related to the black aurora.

http://pparc.gp.tohoku.ac.jp/~tsakanoi/

## Samara, Marilia

### Ground-based Imager Observations of Fast Auroral Pulsations Conjugate to THEMIS Electric Field Measurements

Samara, Marilia[1]; Michell, Robert G.[1]; Bonnell, John[2]

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2. Space Science Laboratory, University of California, Berkeley, Berkeley, CA, USA

We present all-sky imager observations from Poker Flat, Alaska that are conjugate to in situ electric field measurements from onboard the THEMIS spacecraft. During times of pulsating aurora in the all-sky imager data, the THEMIS electric field data show enhancements in the power corresponding to the frequency range of whistler mode chorus. Recent observations of the temporal characteristics of pulsating aurora closely parallel those of typical chorus elements, such as those observed in the Cluster and THEMIS data. We present analysis of several events where there was active pulsating aurora over Alaska and high resolution electric field data from the THEMIS spacecraft, making a direct connection between enhanced wave power in situ and active fast pulsations. The high temporal resolution of the imager used (30 frames per second) will enable us to focus on the pulsations with frequencies in the range of 1 to 15 Hz, which ubiquitously occur with the slower pulsations of 0.1 to 0.3 Hz that have been shown to be associated with discrete chorus elements. The intensity of the aurora at these higher frequencies will be compared to the in situ wave data for correlations with waves identified in the electric field power.

## Sandahl, I.

### Equatorial signatures of an auroral bilge and a transpolar arc at 19 MLT observed by Cluster

Yamauchi, Masatoshi[1]; Nilsson, H.[1]; Lundin, R.[1]; Sandahl, I.[1]; Stenberg, G.[1]; Dandouras, I.[2]; Reme, H.[2]; Andre, M.[3]; Lindqvist, P.[4]; Daly, P.[6]; Kronberg, E.[6]; Ebihara, Y.[5]; Frey, H[7]; Balogh, A.[8]

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2. CESR, Toulouse, France
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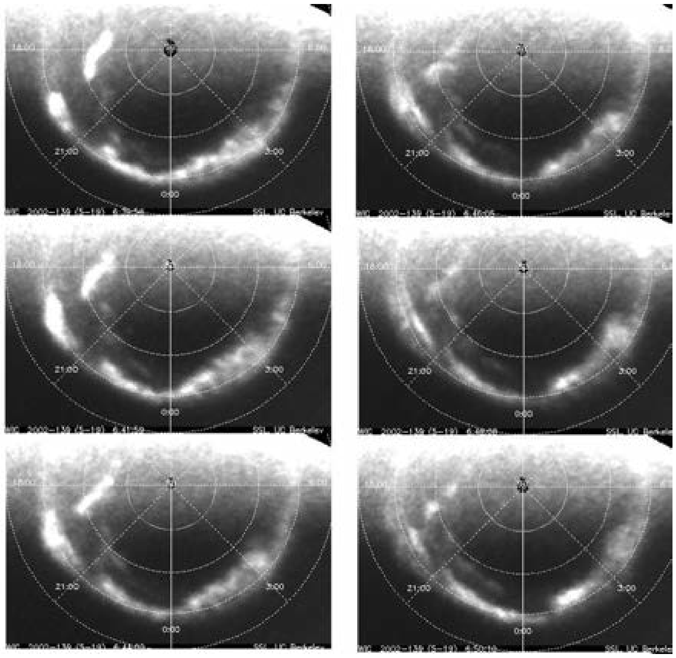
4. KTH, Stockholm, Sweden
5. Nagoya U, Nagoya, Japan
6. MPS, Katlenburg-Lindau, Germany
7. UCB, Berkeley, CA, USA
8. ICL, London, United Kingdom

On 19 Mays 2001, Cluster traversed equatorial conjugate region of auroral bulge and filamentation of transpolar arcs at 19 MLT during substorm expansive phase. Corresponding to the auroral bulge, the spacecraft observed sudden change in both DC field and energetic ion population, which turned out to be a solitary structure that is propagating the same velocity as the auroral bulge with respect to the magnetic field. This is the first observation that linked magnetospheric solitary structure and the auroral bulge. The solitary structure is unexpectedly maintained by the main carrier of the ring

current. Corresponding to the filamentation of the transpolar arc, all spacecraft simultaneously observed sudden onset of bi-directional sub-keV beam, change of energetic ions, and DC and AC electromagnetic disturbances. This demonstrates how the bi-directional beams relevant to the transpolar arc are formed.



Auroral images of nearly 2 min interval taken by IMAGE/FUV. Cluster traversed equaotrial toward higher latitude at arround 19 MLT, first at conjugate regions of auroral bulge, and several minutes later at conjugate region of poleward bright aurora (transpolar arc).

## Sandahl, Ingrid

### Deducing spatial properties of auroral primary particle distributions from ground-based optical imaging

Sandahl, Ingrid[1]; Axelsson, Katarina[1]; Sergienko, Tima[1]; Brändström, Urban[1]; Gustavsson, Björn[2]

1. Swedish Institute of Space Physics, Kiruna, Sweden
2. University of Southampton, Southampton, United Kingdom

The distribution of particles impinging on the upper atmosphere constitutes the most important link between magnetospheric processes and the optical aurora. Particle measurements from satellites and sounding rockets give the most exact information about the primary particle distribution, but they are only able to provide snapshots and statistical results. With ground-based imaging, on the other hand, it is possible to record the aurora over a large area for an extended period of time, and it is therefore of great interest to be able to deduce properties of primary particle distributions from optical data. So far, the most successful methods have relied on different emission intensity ratios, but these methods only work well for field-aligned measurements. This is obviously a severe limitation. In this paper we discuss ways to obtain information on primary particles away from magnetic zenith. In a recent study we have used images of the auroral red and green line emissions obtained from different ALIS stations to estimate the maximum deviation from magnetic zenith of the measurement direction for which the results are reliable. Taking the altitude difference between the red and green line emission peaks (about 100 km) into account we find that the green to red intensity can be used to reconstruct auroral electron parameters for directions up to 30 degrees from magnetic zenith. Implications for magnetospheric processes in selected cases, as well as interpretation problems, will be discussed.

## Sangalli, Laureline

### Estimating the Peak Auroral Emission Altitude from All-sky Images

Sangalli, Laureline[1]; Gustavsson, Björn[2]; Partamies, Noora[1]; Kauristie, Kirsti[1]

1. Finnish Meteorological Institute, Helsinki, Finland
2. Lancaster University, Lancaster, United Kingdom

The MIRACLE network monitors auroral activity in the Fennoscandian sector of Europe. Network stations cover the range of 55° to 57° magnetic latitude North and span two hours in magnetic local time. Some of the MIRACLE network stations include digital all-sky cameras (ASC). Three different types of ASC are currently in use: systems with an image intensifier in front of a CCD (iCCD), systems with electron multiplying CCD (emCCD) and color CCD. Both iCCD and emCCD cameras in the MIRACLE network operate at three different wavelengths: 427.8 nm, 557.7 nm and 630.0 nm. Each wavelength is selected using narrow band filters on a filter wheel placed in front of the CCD. For the color cameras, a color filter array is embedded directly on the chip. A color image is then synthesized from the recorded values in neighboring pixels (corresponding to different wavelength ranges). Our goal is to evaluate the peak auroral emission altitude using ASC images at different stations pairs. We adapted the AIDA software package developed by Björn Gustavsson in Kiruna for ASC images. Our first step consists in performing the geometric star calibration of the different imagers. Our second step is to use the position calibrated images at two (or more) different stations for triangulation and tomography. Ultimately, we want to use the AIDA triangulation and tomography software on a large number of images (starting from 1996) in order to determine the peak auroral emission altitude statistically for different conditions.

## Sato, Natsuo

### Dynamic tracing geomagnetic conjugate points using synchronous auroras (*Invited*)

Sato, Natsuo[1]; Motoba, Tetsuo[1]; Kadokura, Akira[1]; Hosokawa, Keisuke[2]; Bjornsson, Gunnlaugur[3]; Saemundsson, Thorsteinn[3]

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2. University of Electro-Communications, Tokyo, Japan
3. Science Institute, University of Iceland, Reykjavik, Iceland

The electrons captured in the Earth's magnetosphere are basically constrained to move toward the Northern and

Southern Hemispheres along the geomagnetic field lines. Thus, bright nighttime auroras are expected to appear simultaneously in both the hemispheres. Simultaneous observations of interhemispheric conjugate auroras provide a unique opportunity to examine how and where the invisible geomagnetic field lines connect the two hemispheres. Syowa Station in Antarctica and stations in Iceland form an ideal set of observatories to study geomagnetically conjugate optical auroras in the auroral zone. A campaign of conjugate auroral observations using all-sky TV cameras has been carried out since 1984 during the equinox periods. We will show some examples of conjugate auroras that were simultaneously acquired with all-sky TV cameras situated at two geomagnetically conjugate points, at Tjornes in Iceland and at Syowa Station in Antarctica. Using selected similar conjugate auroras the dynamic tracing of footprint of real geomagnetic conjugate point of Syowa, with temporal and spatial resolution of ~10 minute and ~10 km, was firstly possible. Dynamic displacement of conjugate point was strongly affected by the orientation of interplanetary magnetic field (IMF) and development of magnetospheric substorm.

## Semeter, Joshua L.

### Coherence in auroral fine structure (*Invited*)

Semeter, Joshua L.[1]

1. Center for Space Physics, Boston University, Boston, MA, USA

The aurora exhibits spatial and temporal coherence across multiple scales. This talk considers fine-scale coherence in both the optical aurora and the impacted ionospheric plasma collectively. When observed at sufficiently high resolution, the discrete aurora has been found to be comprised of dynamic packets of narrow outward-propagating arcs of <100-m width, suggestive of the field pattern expected in an inertial Alfven cone. These arc packets, in turn, are well correlated in space and time with coherent (non-thermal) backscatter observed by incoherent scatter radar (ISR). This correlation has been well established and extensively discussed in a phenomenological sense, but the theory connecting these disparate domains of observation remains incomplete. We review recent experiments conducted with the electronically steerable Poker Flat ISR (PFISR) and collocated optical instruments suggesting that the physical picture is more nuanced than previously thought. heaviside.bu.edu

## Song, Yan

### Alfvenic Generation of Discrete Auroral Arcs

Song, Yan[1]; Lysak, Robert L.[1]

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Parallel electric fields are important and crucial for the formation of discrete auroras. Based on a dynamical theory (Song and Lysak, 2006), the generation of parallel electric fields in the auroral acceleration region, for both quasi-static (inverted-V) and Alfvenic auroras, should be a result of the dynamical interaction between the generator, the acceleration region and the ionosphere. The interaction must have an Alfvenic nature, since (i) the Poynting flux, a major energy source for auroral formation, is carried by Alfven waves, and (ii) the dynamical formation of parallel electric fields is caused by the interaction of Alfven waves or Alfvenic disturbances. While the kinetic Alfven wave (KAW) theory emphasizes the Alfvenic nature of the formation of parallel electric fields for small perpendicular scale Alfven waves, they only explain the observation of auroras with a broad band spectrum, rather than the classical inverted-V distribution. The generation of parallel electric fields in the inverted-V region has been mostly discussed by using quasi-steady models and theories, such as the Knight relation or static double layer models. These models and theories are mostly based on the assumed existence of a parallel electric field, without explaining how the parallel electric field is formed. By applying Alfven wave packet dynamics, we will illustrate why the formation of quasi-static electric fields must have an Alfvenic nature. The nonlinear interaction between the incident and reflected Alfvén wave packets or Alfvén wave fronts in the auroral acceleration regions can cause a local enhancement of azimuthal magnetic flux. This local dynamo effect supports and maintains the parallel electric fields, where the direction of the parallel electric fields is the same as the direction of field-aligned currents. The time scale of sustained parallel electric fields depends mainly on the time period of the release of the azimuthal magnetic flux. By emphasizing the generation of parallel electric fields in a simplified two fluid case, we improve the description of parallel electric fields associated with the KAW, suggesting a more comprehensive understanding of the relationship between KAW and auroral acceleration. We will compare theoretically the temporal and spatial scales of parallel electric fields in quasi-static aurora and in Alfvenic aurora cases.

## Soobiah, Yasir I.

### A search for auroral-type ion beams in the Martian topside ionosphere

Soobiah, Yasir I.[1]; Barabash, Stas[1]; Lundin, Rickard[1]; Nilsson, Hans[1]; Leblanc, Francois[2]; Witasse, Olivier[3]; Winningham, David[4]

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2. Service d'Aéronomie, CNRS/IPSL University of Versailles Saint-Quentin, Verrières-le-Buisson, France
3. Research and Scientific Support Department, ESTEC ESA, Noordwijk, Netherlands
4. South West Research Institute, San Antonio, TX, USA

We present the results of investigations by the Analyzer for Space Plasmas and Energetic Atoms (ASPERA-3) Ion Mass Spectrometer (IMA) on Mars Express (MEX) into the possible links between particle signatures surrounding the "mini-magnetospheres" of Mars with auroral UV emission as observed by MEX SPICAM UV Spectrometer. We first present examples of particle signatures from the "mini-magnetospheres". These are electrons with peaked distributions in differential energy flux and precipitating electrons at suprathermal energies as measured by the MEX ASPERA-3 Electron Spectrometer (ELS). This is compared to ion measurements by IMA to search for ion beams we expect to be present during the Martian aurora. In the most dynamic case, we have observed the energy dispersion of both electrons and heavy ions of planetary origin (from a few eV to a few hundred eV over a time scale of several tens of seconds). The investigation will attempt to understand in greater depth than before, the conditions in the space plasma environment of Mars that lead to observations of aurora. This is realised by studying the relationship these auroral-type events have with solar wind conditions over twelve months of data obtained during two close conjunctions between Earth and Mars.

## Stallard, Tom

### Clues on Ionospheric Electrodynamics from IR Aurora at Jupiter and Saturn (*Invited*)

Stallard, Tom[1]

1. Physics and Astronomy, University of Leicester, Leicester, United Kingdom

The auroral region of Jupiter and Saturn are highly complex and the way the ionosphere in these regions connects to the surrounding space environment remains a matter of considerable scientific debate. One of the best ways to understand the currents that flow through this region is by directly observing the flow of ions in the upper atmosphere. Using high-resolution spectroscopy from ground-based telescopes, it is possible to do just this. By understand the ion winds within the ionosphere, we are able to understand the source regions within the magnetosphere or solar wind that the magnetic field lines that pass through the ionosphere connect with. In addition, we currently have a limited understanding of the energy distribution in the upper atmospheres of the Gas Giants, with a considerable excess of heat compared with the amount expected from solar heating. One of the leading potential energy sources that provides this additional heating is through aurorally driven electrodynamics near the poles. Thus, by understanding the way ions flow in the ionosphere, we can directly link the magnetosphere, ionosphere and thermosphere and attempt to gain a full understanding of the way energy flows into the planet from above.

## Strangeway, Robert J.

### The Relationship Between Magnetospheric Processes and Auroral Field-Aligned Current Morphology

Strangeway, Robert J.[1]

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Within the magnetosphere the primary sources of field-aligned currents are either field-aligned gradients in vorticity, carried by shear-mode Alvén waves, inertia-driven currents, or plasma pressure gradients. Flow braking might be thought of as a source of inertial currents, while field-aligned closure currents associated with the partial ring current are an example of pressure-gradient currents. In the ionosphere, on the other hand, field-aligned currents are associated with either flow vorticity or conductivity gradients. Ionospheric vorticity-related field-aligned currents are mainly given by the divergence or convergence of Pedersen currents, while gradients in both Hall and Pedersen conductivities can result in field-aligned currents. The fundamental processes that result in aurora can therefore be thought of in terms of field-aligned currents that flow to match the magnetospheric and ionospheric boundary conditions. Data from the Fast Auroral Snapshot (FAST) small explorer spacecraft can provide insight into the different physical processes responsible for the aurora. Specific topics that we will review include the relationship between ionospheric flow vorticity in comparison to magnetospheric plasma pressure gradients, the multi-layered structure of the substorm current wedge system, and the relative importance of Hall currents in driving secondary field-aligned current systems.

## Swift, Daniel W.

### Fast Earthward Flows, Alfven Waves and Auroral Acceleration

Swift, Daniel W.[1]

1. Geophysical Institute, University of Alaska, Fairbanks, AK, USA

Global-scale hybrid code simulations show that fast Earthward flows are generated by the relaxation of an extended tail field, which is seen as dipolarization. The fast flows are broken when the plasma encounters the stronger near-Earth dipole field. Turbulence is generated in the region where the flow is broken. The turbulent region radiates shear Alfven waves which propagate along field lines toward the auroral ionosphere. The turbulent region also radiates magnetosonic mode waves. These waves are the likely cause of the Pi2 pulsations seen as precursor to auroral activation. Simulation results of auroral electron acceleration by inertial Alfven waves will also be presented. Simulations show both upward and downward acceleration. Thus, some of the aurora can be the result of upward acceleration of electrons in the conjugate hemisphere. There are also two acceleration processes. One is impulsive acceleration by electrostatic shock-like structures that form from non-linear steepening of inertial Alfven waves. The other acceleration process is by resonant trapping of electrons in a wave trough with an accelerating phase velocity. These two simulations provide a direct connection between events taking place in deep space and the acceleration of auroral electrons in a way that demands discrete structure so characteristic of auroral forms. The acceleration process is critically dependent on having perpendicular wavelengths comparable to or smaller than the electron inertial length in the acceleration region. The still missing element in this chain is a process for filamentation of the currents propagated by the Alfven waves.

## Sydorenko, Dmytro

### Simulation of Ionospheric Feedback Instability in the Ionospheric Alfven Resonator

Sydorenko, Dmytro[1]; Rankin, Robert[1]

1. Department of Physics, University of Alberta, Edmonton, AB, Canada

Intense Alfven waves often accompany auroras and may accelerate auroral electrons as well. In the vicinity of the Earth, propagation of Alfven waves with frequencies in the range of 0.1-10 Hz is strongly affected by the ionospheric Alfven resonator (IAR). The IAR forms between the ionosphere and the Alfven speed gradient at the altitude of a few thousand km, which is below a typical auroral electron acceleration region. The intensity of Alfven waves in the IAR may grow rapidly due to the ionospheric feedback instability [Lysak, 1991], when the ionospheric conductivity changes synchronously with the incident wave. The energy source for the instability is the background convection current and electric field in the ionosphere. Variation of the conductivity occurs due to (i) wave-induced modulation of precipitating energetic electron flux and (ii) plasma heating by the wave electric current. In order to investigate interaction between the Alfven waves and the Earth ionosphere, a hybrid fluid-kinetic numerical model of low-altitude auroral flux-tubes has been developed. The model is azimuthally symmetric, it considers a two-dimensional area in the meridional plane of the Earth bounded by dipole geomagnetic field lines from the Northern and Southern sides, by an ionosphere at the bottom and by the open-end boundary at the top (altitude about 10000 km). The Alfven waves are injected into the system through this high-altitude boundary. The magnetospheric plasma is represented by oxygen and hydrogen ion fluids, the electrons are represented either as a fluid or kinetically, using the water-bag approach for solution of the drift-kinetic Vlasov equation [Sydorenko et al., 2008]. The ionosphere is represented as a layer of collisional multi-component plasma with thickness of a few hundred km, which contains electrons and the following neutrals and single-charged positive ions: atomic and molecular nitrogen, atomic and molecular oxygen, nitric oxide. Initial equilibrium profiles of densities and temperatures of the ionospheric species are given by IRI-2007 and MSIS-86 models [available at http://nssdcftp.gsfc.nasa.gov/models]. The motion of the ionosphere components is omitted. Modification of the densities is related to the modification of the rates of included chemical reactions [Schunk, 1988]. Modification of the temperatures is due to variation of heating by the wave electric current, time-dependent external sources, and collisions with other species. In addition to the feedback instability studies, the model can be used to investigate excitation of Alfven waves in experiments on artificial heating of the ionosphere. In hybrid regime with kinetic electrons it can be used to study electron acceleration by Alfven waves.

Lysak, R. L. (1991), J. Geophys. Res., 96, 1553. Schunk, R. W. (1988), Pure Appl. Geophys., 127, 255. Sydorenko, D., R. Rankin, and K. Kabin (2009), AGU fall Meeting, December 14-18, 2009, San Francisco, CA, Abstract SM41B-1723.

## Uozumi, Teiji

### AKR modulation and Global Pi 2 oscillation: Jan. 24, 1997 event

Uozumi, Teiji[1]; Yumoto, Kiyohumi[1, 2]; Tokunaga, Terumasa[2]; Solovyev, S. I.[3]; Shevtsov, B. M.[4]; Marshall, R.[5]; Liou, Kan[6]; Ohtani, S.[6]; Abe, S.[1]; Ikeda, A.[1]; Kitamura, K.[7]; Yoshikawa, A.[1, 2]; Kawano, H.[1, 2]; Itonaga, M.[8]

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8. Yamaguchi University, Yamaguchi, Japan

A transient geomagnetic pulsation Pi 2 is well recognized to occur accompanied with auroral breakup [e.g. Sakurai and Saito, 1976], and accepted as an onset indicator of magnetospheric substorm [e.g. Rostoker et al., 1980]. Some Pi 2 are associated with small nightside auroral transient events (e.g., pseudo-breakups) [Liou et al., 2000]. Morioka et al. [2005] demonstrated that a clear auroral kilometric radiation (AKR) sometimes occurred without any typical substorm signatures characterized by auroral electrojet enhancement on the ground, tail current disruption in the near-Earth plasma sheet, and energetic particle injection from the plasma sheet. Then they emphasized that the onset of AKR is one of the elementary components of the contracted substorm same as auroral brightening on the contracted oval and Pi 2 occurred with pseudo-breakup. In order to investigate a cause-and-effect relationship between Pi 2 and AKR, we analyzed an isolated substrom event (AL˜30nT, AE˜40nT) occurred around 1019UT on January 24, 1997, which was accompanied with isolated Pi 2 and AKR. We found that the time-derivative of the height-integrated AKR power flux, which was observed by Polar satellite, oscillated in similar wave form to the mid-latitude D component and the low-latitude H component Pi 2 without any significant phase delay (correlation coefficients were 0.76 and 0.74, respectively, with the delay time of $|dT| \leq 3s$). The Pi 2 event was observed at six stations located in the dusk sector from high-latitude to near-magnetic equatorial region along 210deg magnetic meridian and one midnight low-latitude station belonging MAGDAS/CPMN. The initial movement of Pi 2 occurred concurrently among all the stations in both H and D components. The D component Pi 2 oscillation synchronized among all the station and also low-latitude H component Pi 2. The oscillation behavior of the initial movement of the H component in high- and mid-latitude and entire D component oscillation can be explained by the well-known substorm current wedge (SCW) model for Pi 2, though the propagation mechanism of the magnetic

perturbation from the oscillating SCW to ground stations has not been specified yet. On the other hand, the H component oscillation in the high- and mid-latitude Pi 2 exhibited the propagation signature. Pi 2 onset preceded the AKR breakup about 40s. The temporal relation between the time-derivative of AKR power and ground Pi 2 suggests that the integrated AKR power was modulated synchronously with the oscillation of the SCW, which was inferred from the ground Pi 2 signature.

## Uritsky, Vadim

### Turbulent signatures of bursty bulk flows in mutispectral aurora

Uritsky, Vadim[1]; Donovan, Eric[1]; Liang, Jun[1]; Spanswick, Emma[1]; Knudsen, David[1]; Liu, William[2]

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2. Space Science and Technology Branch, Canadian Space Agency, Saint Hubert, QC, Canada

Bursty bulk flows (BBF) are commonly observed in the magnetotail plasma sheet for a variety of geomagnetic conditions. These flows are able to generate plasma vortices and the associated field-aligned currents coupling to the ionosphere and causing conjugate auroral precipitation patterns. In this talk, we discuss a new scenario for the BBF – ionosphere interaction based on the anisotropic turbulence in the flow-braking region of the magnetotail. We argue that the decelerating BBFs can energize transient magnetic and velocity shears near the inner edge of the plasma sheet producing a highly dynamic and topologically complex field-aligned current system which should inevitably modulate the auroral response. The predicted ground signature of this process is a transient multiscale perturbation of the ionospheric currents, and an optical auroral emission involving a wide range of spatial and temporal scales. Despite a limited width of the magnetotail flow channel, the auroral footprint of a BBF can occupy a significant interval of magnetic local times. The proposed scenario is supported by MHD simulation results and multispectral auroral observations.

## Vasyliunas, Vytenis M.

### Dynamical Origin of Ionospheric and Birkeland Currents Associated with the Aurora

Vasyliunas, Vytenis M.[1]

1. Max-Planck-Institut fuer Sonnensystemforschung, Katlenburg-Lindau, Germany

The common description of ionospheric currents as driven by electric fields and of Birkeland (magnetic-field-aligned) currents as resulting from the divergence of perpendicular currents either in the magnetosphere or in the ionosphere constitutes a mathematically convenient formulation of necessary conditions for equilibrium, not a representation of the actual physical processes that establish and maintain the equilibrium. Physically, on space and time scales larger than those of electron plasma oscillations, the electric current is determined by the curl of the magnetic field, which in turn is determined by the deformation of the field in response to stresses acting upon the plasma. Pedersen and Hall currents in the ionosphere are driven by a bulk flow differenve between the plasma and the neutral atmosphere, the magnetic field becoming deformed until the Lorentz force balances the plasma-neutral friction. Birkeland currents between the ionosphere and the magnetosphere are determined by the parallel curl of the magnetic field; in the case of elongated structures such as auroral arcs, this is primarily the shear of the field lines. If the initial brightening of the equatorial arc at substorm onset is ascribed to enhanced acceleration/precipitation of electrons due to an increase of upward Birkeland current, the initiating physical process must be one that enhances the associated magnetic field shear at the arc; this implies a definite differential motion of the plasma on both sides of the arc, the direction of which depends on whether the process is initiated in the magnetosphere or the ionosphere. Consequences of this concept for theories of the substorm onset will be explored.

## Vogt, Marissa F.

### An Improved Mapping of Jupiter's Auroral Features to Magnetospheric Sources

Vogt, Marissa F.[1, 2]; Kivelson, Margaret G.[1, 2]; Khurana, Krishan K.[1]; Walker, Raymond J.[1, 2]; Bonfond, Bertrand[1, 3]; Grodent, Denis[3]; Radioti, Aikaterini[3]

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Jupiter's auroral emissions are linked to different magnetospheric processes than those that drive the Earth's aurora. For example, the main auroral emissions at Jupiter are associated with the breakdown of plasma corotation in the middle magnetosphere and not with the boundary between open and closed magnetic flux. Satellite footprints form another major component of the Jovian auroral emissions for which there is no terrestrial analog. Understanding the magnetospheric processes that produce Jupiter's polar auroral features is difficult because global field models are inaccurate beyond the inner magnetosphere ($< 30\ R_J$). Therefore, we have mapped contours of constant radial distance from the magnetic equator to the ionosphere in order to map auroral features to their magnetospheric sources. Instead of following model field lines, we require that the magnetic flux in some specified region at the equator equals the magnetic flux in the area to which it maps in the ionosphere. This approach allows us to identify the magnetospheric sources of Jupiter's three polar auroral regions: the active region, which is very dynamic and is characterized by the presence of flares, bright spots, and arc-like features; the swirl region, which is the most poleward of the three regions and displays patchy, ephemeral emissions that exhibit turbulent, swirling motions; and the dark

region, which is located on the dawn side, and, as its name suggests, displays dark in the UV. We find that the active region maps to field lines beyond the dayside magnetopause that can be interpreted as Jupiter's polar cusp; the swirl region maps to lobe field lines on the night side and can be interpreted as Jupiter's polar cap; the dark region spans both open and closed field lines and must be explained by multiple processes. Additionally, we conclude that the flux through most of the area inside the main oval matches the magnetic flux contained in the magnetotail lobes and is probably open to the solar wind.

http://www.igpp.ucla.edu/people/mvogt/mapping/

## Watt, Clare

### Conversion of Poynting Flux to Electron Energy Flux by Shear Alfvén Waves

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Evidence is growing in support of the idea that shear Alfvén waves are responsible for some of the auroral electron acceleration in the Earth's magnetosphere. In-situ observations at 4-7$R_E$ radial distance indicate that shear Alfvén waves have enough Poynting flux to supply the electron energy flux needed to explain auroral displays observed at conjugate points in the ionosphere. However, the exact details of how and where the shear Alfvén waves convert electromagnetic energy to electron kinetic energy are unknown. In the absence of multiple in-situ measurements along auroral field lines, numerical simulations and theory can provide the required insight into the region where the energy conversion takes place. Self-consistent simulations of the wave-particle interaction between shear Alfvén waves and warm plasma demonstrate that the energy conversion process in warm plasma is nonlinear, with electron trapping dominating the electron dynamics in regions close to where the wave develops short perpendicular scales. This complicated nonlinear interaction between waves and particles suggests that the conversion of wave energy to particle energy may be a function of the wave amplitude. We present results from multiple simulations of shear Alfvén waves which investigate how much precipitating electron energy flux can be expected as a result of waves of different amplitude and perpendicular scale length. We compare these numerical predictions with predictions from in-situ measurements.

## Wiltberger, Michael J.

### Using satistical Methods to calibrate auroral models in global scale magnetosphere-ionosphere simulations

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Ionospheric conductance plays an important role in regulating magnetospheric convection. Modern global magnetospheric models supply information about the location and intensity of auroral electron particle precipitation in order to obtain enhancements to the solar EUV conductance profile. Since global magnetospheric models are based upon magnetohydrodynamic solutions empirical relationships are used to translate the MHD density and temperature into an average energy and flux of precipitating electrons. These relationships include the effects of geomagnetic mirroring and parallel potential along regions strong field aligned currents. Initial calibration efforts of the adjustable parameters in these models have been based upon in-situ DMSP particle data. Applying this technique can be challenging due to the effect of offset errors between the satellite track and the simulation results. Recently we have begun to use modern satistical techniques to determine the optimal values of these parameters based upon space-based auroral imagery.

## Wirth, Lisa

### The Geophysical Institute Magnetometer Array: Making Real-Time Geophysical Measurements Available for Operational Space Weather Needs

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The Earth's magnetic field is constantly changing and requires monitoring for accurate navigational aids and space weather needs. The Geophysical Institute Magnetometer Array (GIMA) consists of twelve magnetometer stations distributed across Alaska cutting the auroral oval. Each station is equipped with a ring-core, fluxgate magnetometer, GPS clock and data logger. Data are returned from each station to the GeoData Center (GDC) run by the Alaska Satellite Facility (ASF) for the Geophysical Institute (GI) at the University of Alaska Fairbanks (UAF). At the GDC, the data are verified, archived, and made available to the space science community. The GIMA web page, at http://magnet.asf.alaska.edu/, provides the data from five stations online in real-time. Additionally, the GIMA web page provides data from non-GIMA magnetometer stations. The GIMA data set available online spans the time period 1994 to the present. In a typical month, there are approximately 30 different users of the data set (some using archival data for event studies, others using real time data for operational space weather forecasting). The GIMA data set is available as ASCII and netCDF data files. The magnetometer data offered by the GDC aids in launch planning for the Poker Flat Research Range, the only university owned scientific rocket launching facility. There is a need to update and modernize the magnetometer array due to the evolving science of geomagnetism and demands from the scientific community. This will advance scientific research characterizing the Earth's magnetic field.

## Xing, Xiaoyan

### Azimuthal Pressure Gradient in the Near-Earth Plasma Sheet and Associated Auroral Development Soon Before Substorm Onset

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The azimuthal plasma pressure gradient in the near-Earth plasma sheet makes crucial contributions to field-aligned current (FAC) formation. Numerical simulations and statistical observations have shown that a plasma pressure peak tends to build up in the pre-midnight region of the near-earth plasma sheet during the substorm growth phase due to enhanced magnetic drift. This leads to azimuthal pressure gradients in this region. The temporal variation of the azimuthal pressure gradient may provide an indication for the FACs variations associated with the substorm growth phase and thus may setup a plasma sheet pre-condition for the substorm onset being triggered near this region. We take advantage of two of the THEMIS spacecraft separated azimuthally near the orbit apogee and investigate the azimuthal plasma pressure gradient in the R~10-12 RE region. Equatorial plasma pressure is estimated by removing the curvature force effect. Four events with the spacecraft footprints mapped very close to the aurora onset region were selected. Three of them showed substantial duskward pressure gradient enhancement 2-5 min before onset. A late-growth-phase electron auroral arc, which became the substorm onset arc, was found to intensify simultaneously with the pressure gradient enhancement. The other event showed almost no change of azimuthal pressure gradient before a weak onset, at the same time neither growth-phase auroral arc intensification was found near the spacecraft footprints, nor did onset occur along an observable arc. These results indicate that the duskward azimuthal pressure gradient enhancement associated with enhanced upward FACs during the late-growth-phase may provide important energy redistribution for the intensification of the growth-phase auroral arc soon before it breaks up and set up conditions for substorm onset to occur along such an arc.

## Yaegashi, Ayumi

### Spatiotemporal Variations and Generation Mechanisms of Flickering Aurora

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Flickering aurora is characterized by the intensity modulation with a dominant frequency of about 8-15 Hz and by the horizontal scale with a range of several kilometers. It has been suggested that electromagnetic ion cyclotron (EMIC) waves and/or inertial Alfven waves (IAW) contribute to generate the flickering aurora via the interference. However, the supporting evidence was limited up to ~16 Hz, the Nyquist frequency of video sampling rate, in the past imaging measurements, and the further extension to higher frequency domain is still unknown. Here we conducted ground-based measurements of EMCCD camera and ELF search coil magnetometers in Alaska from December 2009 to April 2010. Imaging data were obtained with a sampling rate of 100 Hz, and its field of view and spatial resolution are 16km x 16km, 260m x 260 m, respectively, mapping at an altitude of 100 km. The ELF search coil magnetometers were installed at the same place and operated with 400 Hz sampling rate. In this study we quantitatively clarify the small-scale flickering spots with a few km and their frequency variation higher than usual ranging up to 50 Hz as obtained with our new measurement system, which are important to understand the generation mechanisms of flickering aurora in broader frequency range than obtained in the past. We apply a two-dimensional FFT analysis on each image to estimate the spatial wavelength of flickering structure. Also, we apply FFT coherence and phase analysis to investigate the temporal variation of a series of images. We discuss several types of flickering aurora in detail; one is characterized by unusually frequency range of 30-40Hz with small spot-like structures of 2-3km scale and the other types are line-like aurora, rotating flickering etc. We suggest hypothesis that He+ or H+ EMIC waves may contribute to generate the 30-40Hz flickering aurora by similar mechanisms operated in the O+ EMIC waves generating 8-15 Hz variation. We will extend the analysis to the other events to generalize the hypothesis and to elucidate the fundamental mechanisms of flickering aurora.

## Yoshikawa, Akimasa

### Synthesis formulation for conductivity evolution near the ionospheric E-region including current carrier transition and energetic electron precipitation effects at the finite field-aligned current region

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A synthesis equation for ionospheirc conductivity evolution taking into account the parallel potential drop at the aurora-accelerated region and current-carrier transition process from electron to ion at the finite field-aligned current (FAC) region is developed. In this equation, ionization ratio by monoenergetic electron precipitation is embodied by the upward FAC amplitude, and the electron flux divergence has roles of the plasma transportation, production, and evacuation effect when there is no precipitation effect. Using this equation, we find that the plasma density does not transfer to the ExB direction as predicted by previous model, rather it advects against the diverging (converging) current from (into) the FAC region. The propagation speed of the plasma density is proportionally increasing with the increase of the upward FAC and of which propagation direction has strongly controlled by the converging Cowing current into the upward FAC region. The nature educed from this synthetics equation for conductivity evolution may account the self-organized evolution of the westward-traveling surge during auroral substorm.

## Zhou, Xiaoyan

### Discrete Shock-Aurora in Dawn/Dusk: The Best Manifestation of Magnetic Shearing?

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As a manifestation of the dayside outer magnetospheric dynamics, the shock-aurora reveals interactions along the chain of the solar wind pressure discontinuity – magnetosphere – ionosphere. In UV remote sensing images, shock-aurora appears to have an onset near local noon; then to be followed by a fast anti-sunward propagation along the dawn and dusk auroral oval to midnight within ~10 min. The ionospheric speed is very high at ~6-11 km/s, which is much faster than the typical auroral speed of < 1 km/s, but matches the shock speed in the solar wind. Data from FAST and DMSP showed that the particle precipitation structure is low-energy electrons (~< 1 keV) precipitating along the poleward boundary of the oval and high-energy electrons (~1-10 keV) at lower latitudes adjacent to the boundary. The soft electrons precipitate along highly structured field-aligned currents, but the hard electrons are highly isotropic with a full loss cone. Images from an all-sky imager (ASI) on Svalbard (when it was near local noon) showed that the aurora along the poleward boundary is red arcs that are caused by soft electrons. Those arcs are in east-west orientation and moving equatorward, which are very likely caused by the dayside reconnection. The aurora on the oval is mainly green diffuse aurora that is caused by hard electrons and is expanding anti-sunward. Strikingly, the green diffuse aurora was more intense than the red arcs during the shock compression. Interestingly, when the ASI is located at the dawnside of the oval during the 18 February 1999 shock-aurora event, in addition to the diffuse aurora in both emissions on the oval, bright beams occurred along the oval poleward boundary. This paper, which focused on this event, will show that the beams rotated towards night with an angular speed at ~0.16°/s that matches a solar wind speed at ~540 km/s if assuming the flank magnetopause at 15 Re. Speculated mechanism of this auroral phenomenon would naturally be the magnetic shearing. A fast release of magnetic shear stresses could establish field-aligned potential drops and convert the differential magnetic energy into kinetic energy of auroral particles. The uniqueness of this shock-aurora event is that the magnetic shearing may have led to the formation of flux tubes along the open and closed field-line boundary. Field-aligned potential drops were established inside the tubes in the auroral acceleration region. So auroral beams were seen near the ionospheric footprint of the tubes and moved towards nightside when the flux tubes on the magnetopause were dragged tailward by the solar wind. Details of the auroral signature and the magnetic shearing mechanism will be discussed more quantitatively in the paper.

## Zhou, Xuzhi

### On the earthward precursor flows in advance of dipolarization fronts

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Earthward-propagating dipolarization fronts, interpreted as thin, vertical current sheets separating plasmas of different origins in the Earth's magnetotail, are usually observed near the leading edge of bursty bulk flows in association with aurora activities. Observations have also shown that bursty bulk flow onset typically precedes dipolarization front arrival by ~ 1 min. Ion distribution functions reveal that earthward flows in advance of front arrival are often caused by the appearance of a new ion population atop a pre-existing plasma sheet component. Particle simulations suggest that this second population, which contributes most to the plasma velocity, is composed of ions that have been reflected and accelerated by the approaching front. The ions are injected earthward upstream of the front, with their regions of accessibility confined by their gyroradii around background Bz. The kinetic picture is well supported by THEMIS statistical studies, and the effects on modifying the current sheet geometry / aurora signatures are discussed.

## Zou, Shasha

### Mutual Evolution of Aurora and Ionospheric Electrodynamic Features during Substorms (*Invited*)

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Substorms are one of the fundamental elements of geomagnetic activity, which involve complex magnetosphere-ionosphere coupling processes and spectacular aurora. We briefly review recent progresses on the relationship between the aurora and ionospheric electrodynamic features during substorms focusing on observations from ground-based radars. Combinations of these radars and optical measurements allow us to study the mutual evolution of the aurora and ionospheric electrodynamics, such as convection flows and current systems. Observations from SuperDARN [Zou et al., 2009a] and PFISR [Zou et al., 2009b] show that nightside convection flows exhibit repeatable and distinct variations at different locations relative to the substorm-related auroral activity near the Harang reversal region, which represents a key feature of magnetospheric and ionospheric convection. Recent statistical results show that the Harang reversal formation near midnight is not sensitive to the sign of the prevailing IMF By [Grocott et al., 2010]. Taking advantage of the simultaneous flow and electron density measurements from PFISR, a current closure relation has been found between the Region 2 and the substorm field-aligned current systems. By synthesizing these observations, a 2-D comprehensive view of the nightside ionospheric electrodynamical features, including electrical equipotentials, flows and FACs, and their evolution associated with substorms has been constructed. Recently it is found that substorm onsets are frequently preceded by equatorward extension of a north-south auroral structure from the polar cap boundary to the east-west pre-existing growth phase arc [Nishimura et al., 2010]. It was suggested that this north-south auroral structure is associated with new and low entropy plasma, which enters the plasma sheet from the separatrix, moves earthward, and then leads to plasma instability responsible for onset near the Harang reversal region. We report recent progress on the ionospheric electrodynamic features of the precursor north-south auroral structures [Zou et al., 2009c]. Grocott, A., et al. (2010),Superposed epoch analysis of the ionospheric convection evolution during substorms: IMF BY dependence, J. Geophys. Res., in press. Nishimura, Y., L. Lyons, S. Zou, V. Angelopoulos, and S. Mende (2010), Substorm triggering by new plasma intrusion: THEMIS all-sky imager observations, J. Geophys. Res., 115, A07222. Zou, S., L. R. Lyons, C.-P. Wang, A. Boudouridis, J. M. Ruohoniemi, P. C. Anderson, P. L. Dyson, and J. C. Devlin (2009a), On the coupling between the Harang reversal evolution and substorm dynamics: A synthesis of SuperDARN, DMSP, and IMAGE observations, J. Geophys. Res., 114, A01205. Zou, S., L. R. Lyons, M. J. Nicolls, C. J. Heinselman, and S. B. Mende (2009b), Nightside ionospheric electrodynamics associated with substorms: PFISR and THEMIS ASI observations, J. Geophys. Res., 114, A12301. Zou, S., Y. Nishimura, L. R. Lyons, S. B. Mende, G. J. Sofko, N. Nishitani, T. Hori, K. Hosokawa (2009c), Substorm onset by new plasma intrusion 4: SuperDARN-THEMIS ASI-POES observations, AGU, Fall Meeting, #SM41B-1711.

## Zou, Shasha

### Multi-instrument observations of a substorm onset: its location and pre-onset sequence

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We present a state-of-the-art ground and space-based imaging study of a substorm that occurred on 12 October 2007. The auroral breakup was observed simultaneously by the Reimei satellite, THEMIS all-sky imager and PFISR radar. The magnetic field line footprint of the Geotail spacecraft was also near the ionospheric location of the substorm onset. These multi-instrument observations allow for detailed study of the breakup location in terms of large and small-scale auroral morphology, particle precipitation and ionospheric convection, which has not been achieved previously. It also allows for identification of details of the sequence leading to the auroral breakup, i.e. poleward expansion. We report the first spaceborne high-spatial and temporal resolution images of a portion of a breakup arc and a wave-like auroral enhancement captured by cameras onboard Reimei. This substorm was isolated and occurred in a thin, only ~1.5° wide, auroral oval. A sudden plasma sheet thinning initiated ~10 min prior to the onset as suggested by observations from PFISR and Geotail. Wave-like auroral enhancements were observed twice at the most equatorward preexisting auroral arc about 3 min and 1 min before the auroral expansion. These enhancements are likely to be caused by a near-Earth instability, such as ballooning instability. Unlike the usual substorm sequence, this most equatorward wavy arc did not develop into the breakup arc,

but remained almost stable until being engulfed by the auroral equatorward expansion from higher latitude after onset. The wave-like auroral enhancement was associated with three fine inverted-V structures and fully embedded within energetic ion precipitation and westward flows. Following this enhancement, an arc formed at higher latitude just adjacent to the PSBL, and was likely a poleward boundary intensification (PBI). This arc then extended southwestward and led to the breakup arc. The breakup arc was located poleward of and separated from the wave-like auroral enhancement. Assuming longitudinal homogeneity of proton precipitation over one degree in geographic longitude, this breakup arc was located within a region without ion precipitation just poleward of the energetic ion precipitation, and in the center of the Harang reversal. The multi-instrument observations suggest the possible existence of a low-entropy flow channel associated with the arc adjacent to the PSBL, which might be associated with instability in the near-Earth plasma sheet responsible for the auroral breakup. Reference: Zou, S., M. B. Moldwin, L. R. Lyons, Y. Nishimura, M. Hirahara, T. Sakanoi, K. Asamura, M. J. Nicolls, Y. Miyashita, S. B. Mende, and C. J. Heinselman (2010), Identification of substorm onset location and pre-onset sequence using Reimei, THEMIS GBO, PFISR and Geotail, J. Geophys. Res., doi:10.1029/2010JA015520, in press.