MAGNETOSPHERES OF THE OUTER PLANETS

Conference in Uppsala, Sweden

12 – 16 June 2017

Program

Swedish Institute for Space Physics (Institutet för rymdfysik, IRF)

Royal Institute of Technology (Kungliga Tekniska högskolan, KTH)

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Special thanks go to Francesco Vallegra for helping to format this programme book.

Monday, June 12

Saturn / Cassini overviews – Chair: David Andrews

09:00 – *Nicholas Achilleos*: Cassini Measurements of Saturn's Magnetic Field: An Overview
09:20 – *Elias Roussos*: Saturn's radiation belts after 13 years of Cassini MIMI/LEMMS observations
09:40 – *Jiang Liu*: Saturn's Global Magnetospheric Current System as Unraveled by Cassini Data
09:55 – *Benjamin Palmaerts*: Pulsations in Saturn's magnetosphere
10:15 – *Gregory Hunt*: Field-aligned currents observations close to Saturn: Past and present
10:35 – **COFFEE BREAK**

Saturn / Magnetosphere structure & dynamics I – Chair: David Andrews

11:15 – *Arianna Sorba*: Investigating the periodic 'flapping' and 'breathing' behaviour of Saturn's magnetodisc using Cassini equinox data
11:30 – *Jamie M. Jasinski*: Flux transfer event observation at Saturn's dayside magnetopause by the Cassini spacecraft
11:45 – *Zhonghua Yao*: Two fundamentally different drivers of dipolarizations at Saturn
12:00 – *Andrew Smith*: A Multi-Instrument Study of Dipolarizations within the Kronian Magnetotail
12:15 – *Zoltan Nemeth*: Closed field line vortices and retrograde plasma motion in the nightside magnetosphere of Saturn
12:30 – **LUNCH BREAK**

Saturn / Magnetosphere structure & dynamics II – Chair: Gabby Provan

14:00 – *Carley J. Martin*: Cassini observations of aperiodic waves on Saturn's equatorial current sheet
14:15 – *David Pisa*: Survey of intense whistler-mode emissions in Saturn's magnetosheath
14:30 – *Ali Sulaiman*: The Impact of Saturn's Non-axisymmetric Magnetosphere on the Solar Wind Flow
14:45 – *Abigail R. Azari*: A Novel Detection and Classification Method for Analysis of Interchange Injection Events at Saturn Using MIMI-CHEMS

Saturn / Cassini proximal orbits I – Chair: Luke Moore

15:00 – *Sheng-Yi Ye*: Cassini RPWS Dust Observation During the F-ring and Proximal Orbits
15:15 – *Edward C. Sittler jr.*: Discovery of Protons between Saturn's F-Ring and G-Ring
15:30 – **COFFEE BREAK**

Saturn / Cassini proximal orbits II – Chair: Luke Moore

16:00 – *Norbert Krupp*: Temporal and spatial variations of energetic ions and electrons in the inner Saturnian magnetosphere: Results of the high-latitude Cassini orbits 2016-2017
16:15 – *Emma Woodfield*: Local effects on Saturn's Electron Radiation Belts by Z-mode, O-mode, Chorus and EMIC waves
16:30 – *Jan-Erik Wahlund*: Saturn Ionosphere – as detected by the RPWS during the proximal orbits
16:45 – *Wei-Ling Tseng*: The Saturnian near-ring plasma environment
17:00 – *Ann M. Persoon* : A Diffusive Equilibrium Model for the Plasma Density from 2.5 to 10 R_S
17:15 – *Michiko W. Morooka*: Dusty Plasma observation of Saturn's faint rings by Cassini/RPWS/LP

Tuesday, June 13

Saturn / PPO - aurora & radio – Chair: Gabby Provan

09:00 – *Laurent Lamy*: Cassini Grand Finale : new insights on the emission region and periodicities of Saturn Kilometric Radiation

09:15 – *Stanley W H Cowley*: Planetary period oscillations in Saturn's magnetosphere

09:35 – *Joe Kinrade*: Tracking the evolution of rotating features in Saturn's magnetosphere using imagery from Cassini's UVIS, VIMS, and INCA.

09:50 – *Xianzhe Jia*: Global Scale Periodic Responses in Saturn's Magnetosphere

10:05 – *Krishan Khurana*: How are Planetary Period Oscillations Generated in Saturn's Magnetosphere?

10:20 – *James O'Donoghue*: The observed effects of "ring rain" on the ionosphere of Saturn

10:35 – **COFFEE BREAK**

Comparative magnetospheres I – Chair: Chihiro Tao

11:10 – *Emma Bunce*: **Tutorial -** Magnetosphere-Ionosphere Coupling at the Outer Planets

11:40 – *Margaret Galland Kivelson*: How are magnetospheric plasmas heated?

12:00 – *William S. Kurth*: Comparisons of Radio and Plasma Wave Observations from Juno and Cassini in Their Similar Orbits at Jupiter and Saturn

12:15 – *Pontus C. Brandt*: Plasma Heating, Large-Scale Injections and Radio Emissions at Saturn, Jupiter and Earth: Conclusions from Cassini and Implications for JUICE Observations of Jupiter

12:30 – **LUNCH BREAK**

Comparative magnetospheres II – Chair: Emmanuel Chané

14:00 – *Peter Delamere*: **Tutorial -** The role of the solar wind for the outer planet magnetospheres

14:30 – *John T Clarke*: The Evidence for Solar Wind Control of Auroral Processes at Jupiter and Saturn

14:45 – *Xin Cao*: Diurnal And Seasonal Variability of Uranus' Magnetosphere

15:00 – *Henrik Melin*: Detection of the infrared aurora of Uranus

15:15 – *Matthew Shultz*: Comparing the Magnetospheres of Planets & Massive Stars

15:30 – **COFFEE BREAK & POSTER SESSION 1**

Wednesday, June 14

Jupiter / Juno I – Chair: Fran Bagenal

09:00 – *Scott Bolton*: Early Results from the Juno Mission
09:20 – *Randy Gladstone*: An Overview of Juno-UVS Observations of Jupiter's Auroras through Perijove 6
09:35 – *George Clark*: Energetic particle measurements at Jupiter by the Juno-JEDI instrument
09:55 – *Robert W. Ebert*: Plasma Observations in Jupiter's Polar Magnetosphere from the Jovian Auroral Distributions Experiment (JADE)
10:15 – *Jack Connerney*: Juno Magnetometer observations in the Jovian magnetosphere
10:30 – **COFFEE BREAK**

Jupiter / Juno II - polar observations – Chair: Fran Bagenal

11:00 – *Sadie Suzanne Tetrick*: Juno spacecraft observations of plasma wave emissions in Jupiter's low-altitude polar regions
11:15 – *Barry H. Mauk*: Particle energization and structuring of Jupiter's main auroral oval as diagnosed with Juno measurements of (>30 keV) energetic particles
11:30 – *Philip Valek*: Observations of low energy plasma in Jupiter's sub-auroral magnetosphere
11:45 – *Frederic Allegrini*: Electron measurements over Jupiter's Poles by the Jovian Auroral Distributions Experiment-Electrons (JADE-E) on Juno
12:00 – *John Leif Jorgensen*: High Energy (>15 MeV) Particle Fluxes in Jupiter's Polar Regions
12:15 – *Philippe LOUARN*: Cyclotron maser mechanism at Jupiter: Juno observations
12:30 – **LUNCH BREAK**

Jupiter / Magnetosphere modelling – Chair: KC Hansen

14:00 – *Jack Connerney*: **[Tutorial]** Magnetic Field Measurements and Derivation of Planetary Magnetic Field Models
14:30 – *Yash Sarkango*: Global Magnetohydrodynamic Simulations of Jupiter's Magnetosphere: Results on Global Configuration and Plasma Circulation
14:45 – *Emmanuel Chané*: Asymmetries in the Jovian magnetosphere
15:00 – **Excursion to Gamla Uppsala**

Thursday, June 15

Jupiter - Solar Wind interaction / Aurora – Chair: Emmanuel Chané

09:00 – *Jonathan David Nichols*: Response of Jupiter's auroras to conditions in the interplanetary medium as measured by the Hubble Space Telescope and Juno

09:20 – *Tomoki KIMURA*: Auroral explosion at Jupiter observed by the Hisaki satellite and Hubble Space Telescope during approaching phase of the Juno spacecraft

09:40 – *Adam Masters*: Revealing how the solar wind interacts with Jupiter's magnetosphere

09:55 – *Denis GRODENT*: Juno, Hubble and James Webb observing Jupiter's aurora

10:10 – *William Dunn*: The Auroral Dynamic Duo - Jupiter's Independent Pulsating X-ray Hot Spots

10:30 – COFFEE BREAK

Jupiter / Aurora II – Chair: Randy Gladstone

11:00 – *Jean-Claude Gérard*: Concurrent ultraviolet and infrared observations of the north Jovian aurora during Juno's first perijove

11:15 – *Vincent Hue*: Juno-UVS observation of the Io footprint during eclipse

11:30 – *Tatphicha Promfu*: The shift of Ganymede's magnetic footprint under influence of plasma pressure anisotropy

11:45 – *Kazuo Yoshioka*: Plasma dynamics around Jupiter's inner magnetosphere deduced by EUV spectra of the Io plasma torus

12:00 – *Rosie Eleanor Johnson*: Jupiter's auroral ionospheric H3+ flows

12:15 – Presentatations for next MOP location

12:30 – LUNCH BREAK

Jupiter aurora and radio III – Chair: Randy Gladstone

14:00 – *Philippe ZARKA*: Radio emissions from Jupiter

14:20 – *Kazumasa Imai*: Source locations of Jupiter's decametric radio emissions measured by the modulation lane method

14:35 – *Corentin LOUIS*: Io-Jupiter decametric arcs observed by Juno/Waves compared to ExPRES simulations

14:50 – *Masafumi Imai*: Statistical beaming properties of Jupiter's decametric radiation using the Juno Waves instrument

15:05 – *James Sinclair*: Evolution and morphology of Jupiter's auroral-related stratospheric heating

15:20 – *Tom Stallard*: Jupiter's non-auroral ionosphere and magnetic equator

15:35 – COFFEE BREAK & POSTER SESSION 2

Friday, June 16

Moons I – Chair: Lorenz Roth

09:00 – *Joachim Saur*: **Tutorial -** Interactions of moon atmospheres and interiors with the giant planets' magnetospheres
09:30 – *Shahab Fatemi*: Kinetic simulations of Ganymede's magnetosphere and the formation of Ganymede's surface brightness asymmetries
09:45 – *Lucas Liuzzo*: A Comprehensive Picture of Callisto's Magnetic Environment during the Galileo Era
10:00 – *Oliver Hartkorn*: Is there an ocean inside Callisto? Revisiting Galileo spacecraft magnetic field measurements.
10:15 – *Witasse Olivier*: JUICE: A European Mission to Jupiter and its Icy Moons
10:30 – COFFEE BREAK

Moons II – Chair: Annie Wellbrock

11:00 – *Frank Crary*: The Alfven wings of Europa and Enceladus
11:15 – *Robert E Johnson*: Sputtering of Large Organic Molecules from Satellites in Planetary Magnetospheres: Modeling Based on Laboratory Studies at Uppsala
11:30 – *Abigail Rymer*: Are the Enceladus Plumes a Hotbed of Negativity?
11:45 – *Darci Snowden*: Cassini at Titan: What have we learned after more than a decade of observations?
12:05 – *Oleg Shebanits*: Titan's ionospheric ions ¬through the solar cycle
12:20 – *Anne Wellbrock*: Observations of photoelectron energy peaks in Titan's ionosphere
12:35 – LUNCH BREAK

Io and Io Torus – Chair: Olivier Witasse

14:00 – *Vytenis M. Vasyliunas*: Plasma transport out of the Io torus: Open questions
14:15 – *Aljona Blöcker*: Io's plasma interaction with Jupiter's magnetosphere: Influence of global asymmetries in Io's atmosphere and volcanic plumes on the plasma environment
14:30 – *Fuminori Tsuchiya*: Enhancement of Jovian magnetospheric plasma circulation due to mass supply change from the satellite Io
14:45 – *Reina Hikida*: Behavior of hot electrons in the Io Plasma Torus during the transient brightenings confirmed by Hisaki/EXCEED observation
15:00 – *Yoshifumi Futaana*: CPEM: An empirical probability model of cold plasma environment in Jovian inner magnetosphere
15:15 – *Carl Schmidt*: Characterizing Io's Plasma Torus at Visible Wavelengths in the Hisaki Era
15:30 – Closing reception

Oral presentations

Abstracts

Monday, June 12 – 09:00

Cassini Measurements of Saturn's Magnetic Field: An Overview

Nicholas Achilleos, Michele K. Dougherty

* University College London

Abstract

The Cassini magnetometer (MAG) has provided us with a rich and extensive dataset of magnetic field measurements, not only of Saturn's internal field but also the many and varied magnetospheric sources of field external to the planet. In this review, we will summarise the development of our understanding in the following main areas: (1) The apparently high degree of axial symmetry of the planet's internal field. (2) The ubiquitous 'planetary period oscillations' in the field, themselves a signature of rotating current systems likely driven by an atmospheric source. (3) The finite lifetime of 'fossil fields' in Titan's ionosphere, and the role of these fields as a signature of previous magnetic / plasma environments to which Titan has been exposed - with obvious application to transitions between magnetosphere and solar wind.

Monday, June 12 – 09:20

Saturn's radiation belts after 13 years of Cassini MIMI/LEMMS observations

Elias Roussos, Peter Kollmann, Norbert Krupp, Chris Paranicas, Donald Mitchell, Stamatios Krimigis, Thomas Armstrong

* Max Planck Institute for Solar System Research

Abstract

The Cassini MIMI instrument suite and its energetic particle detector LEMMS have been exploring Saturn's radiation belts since July 2004, completing nearly 200 crossings through them until June 2017. Besides constructing detailed radiation belt maps, this extensive survey allowed us also to capture the system's dynamics and its characteristic time scales of variability, revealing also the source processes associated with the production or acceleration of MeV electrons and ions. Furthermore, we found that measurements in the radiation belts can be diagnostic for the global state of Saturn's magnetosphere and for geophysical aspects of the planet's moon and ring system. In this review talk we summarise the major findings resulting from MIMI/LEMMS observations in the planet's radiation belts, focusing on the MeV particle populations. We show that the structure and dynamical evolution of the electron and ion components of the radiation belts is weakly coupled and how the study of each component provides different insights into the magnetosphere, the planet, its moons and rings. We will also discuss some of the early findings from Cassini's Proximal Orbits, focusing particularly on the question of whether an energetic particle population exists permanently inside the D-ring and if yes, what its potential source processes are.

Monday, June 12 – 09:40

Saturn's Global Magnetospheric Current System as Unraveled by Cassini Data

Jiang Liu, Krishan Khurana

* University of California, Los Angeles

Abstract

Knowledge about Saturn's magnetosphere can provide valuable information on how moderately-strong planetary field interacts with weak solar wind and how plasma-loading moons affect a planet's magnetosphere. Using ten years of magnetic field data from Cassini, we resolve the global magnetospheric current system of Saturn. The results show that Saturn's current system is similar to that of Jupiter—in most places there is a radially outward current, indicating that the magnetospheric field lines are draped backward, i.e., the magnetosphere is sub-corotational. Beyond 20 Rs to the dusk side of Saturn, however, the radial current is inward, which means that the field lines are draped forward. Therefore, Saturn's magnetosphere is also profoundly affected by solar wind driven convection. The azimuthal current inferred from Cassini data reveals that Saturn has an asymmetric ring current: it is much stronger on the dayside than on the nightside. This asymmetry requires a partial ring current on the nightside, which must be accompanied by Regin-2 type field-aligned currents. Finally, we fit Cassini data into a set of Euler potential forms to build an empirical field model of Saturn's magnetosphere.

Monday, June 12 – 09:55

Pulsations in Saturn's magnetosphere

Benjamin Palmaerts, Elias Roussos, Aikaterini Radioti, Denis Grodent, Norbert Krupp

* Max-Planck-Institute for Solar System Research, Göttingen, Germany

Abstract

The in-situ exploration of the magnetospheres of Jupiter and Saturn has revealed various pulsed phenomena, some of them being periodic. In Saturn's magnetosphere, several studies have reported pulsations with a periodicity of around one hour in the measurements of charged particle fluxes, plasma wave emissions, magnetic field strength and auroral emission brightness. A Cassini multi-instrument overview of these hourly pulsations will be presented. A survey of the quasi-periodic 1-hour energetic electron injections observed in Saturn's outer magnetosphere has been achieved together with an analysis of simultaneous pulsations in the low-frequency radio emissions and in the magnetic field. Quasi-periodic 1-hour brightening of auroral structures associated with magnetopause reconnection has been also reported. Pulsed high-latitude lobe reconnection is a likely common triggering process for brightening of a polar auroral spot associated with the cusp and the high-latitude electron pulsations. Finally, the involvement of magnetopause reconnection in the generation of the quasi-periodic electron injections will be discussed.

Monday, June 12 – 10:15

Field-aligned currents observations close to Saturn: Past and present

Gregory Hunt, S. W. H. Cowley, E. J. Bunce, G. Provan, M. K. Dougherty, I. I. Alexeev, E. S. Belenkaya, V. V. Kalegaev, A. J. Coates

* Imperial College London

Abstract

We will review recent analyses of azimuthal magnetic field data from the Cassini spacecraft during 2008 showing the presence of field-aligned currents in the midnight local time (LT) sector. These showed that in the southern hemisphere, these currents are found to be strongly modulated in form, magnitude, and position by the phase of the southern planetary period oscillations (PPOs). In the northern hemisphere, however, we show that the currents are modulated by both the northern and southern PPO phases, thus giving the first direct evidence of inter-hemispheric PPO currents. We separate currents independent of PPO phase from the PPO-related currents, by exploiting the expected anti-symmetry of the latter with respect to PPO phase. We find that in both hemispheres the PPO-independent (subcorotation) and PPO-related currents are typically co-located and comparable in magnitude, although this connection is yet to be fully elucidated. These results provide a framework to which the present Grand Finale orbits can be compared to, where Saturn's auroral field aligned currents are being explored once more. We will assess how the field-aligned currents have evolved in comparison to the above mention framework established from the 2008 dataset. We will extend comparison of LT with these new data. Using both sets of data will inform for the analysis of the Proximal orbits, where a clear understanding of the azimuthal contribution will be critical.

Monday, June 12 – 11:15

Investigating the periodic 'flapping' and 'breathing' behaviour of Saturn's magnetodisc using Cassini equinox data

Arianna Sorba, Nick Achilleos, Patrick Guio, Chris Arridge, Nick Sergis, Michele Dougherty

* University College London

Abstract

Periodic variations have been observed in many field and particle properties in Saturn's magnetosphere, modulated at a period close to the planetary rotation rate. Magnetic field observations by Cassini's magnetometer instrument suggest that in the outer magnetosphere Saturn's current sheet is periodically displaced with respect to the rotational equator; to a first approximation, it acts as a rotating, tilted disc. This manifests as a 'flapping' mode when observed by the spacecraft. Recent studies suggest the magnetosphere also has a 'breathing' mode, expanding and contracting with a period close to the planetary rotation rate. We model these two modes in tandem by combining a global, geometrical model of a tilted and rippled current sheet with a local, force-balance model of Saturn's magnetodisc. We fit this combined model to Cassini magnetometer data acquired on equatorial orbits from 23 Oct – 17 Dec 2009, during Saturn equinox, chosen so that seasonal effects on the current sheet are minimised. For some passes, our model well characterises the amplitude and phases of the oscillations in the Cassini data, particularly when variations in the magnetosphere's size and hot plasma content are accounted for. However not all passes show clear periodic signatures of the 'flapping' mode, and thus a modified approach is required. Our results suggest a complex relationship between current sheet dynamics, observed periodicities and the rotating current systems of the magnetosphere.

Monday, June 12 – 11:30

Flux transfer event observation at Saturn's dayside magnetopause by the Cassini spacecraft

Jamie M. Jasinski, James A. Slavin, Christopher S. Arridge, Gangkai Poh, Xianzhe Jia, Nick Sergis, Andrew J. Coates, Geraint H. Jones, J. Hunter Waite Jr.

* University of Michigan

Abstract

We present the first observation of a flux rope at Saturn's dayside magnetopause. This is an important result because it shows that the Saturnian magnetopause is conducive to multiple X-line reconnection and flux rope generation. Minimum variance analysis shows that the magnetic signature is consistent with a flux rope. The magnetic observations were well fitted to a constant-α force-free flux rope model. The radius and magnetic flux content of the rope are estimated to be 4600–8300 km and 0.2–0.8 MWb, respectively. Cassini also observed five traveling compression regions (remote signatures of flux ropes), in the adjacent magnetosphere. The magnetic flux content is compared to other estimates of flux opening via reconnection at Saturn.

Monday, June 12 – 11:45

Two fundamentally different drivers of dipolarizations at Saturn

Zhonghua Yao, Denis Grodent, Licia Ray, Jonathan Rae, Andrew Coates, Zuyin Pu, Tony Lui, Katerina Radioti, Jack Waite, Geraint Jones, Ruilong Guo, William Dunn

* Laboratoire de Physique Atmosphérique et Planétaire, STAR Institute , Université de Liège, Liège, Belgium.

Abstract

Solar wind energy is transferred to planetary magnetospheres via magnetopause reconnection, driving magnetospheric dynamics. At giant planets like Saturn, rapid rotation and internal plasma sources from geologically active moons also drive magnetospheric dynamics. In both cases, magnetic energy is regularly released via magnetospheric current re-distributions that usually result in a change of the global magnetic field topology (named substorm dipolarization at Earth). Besides this substorm dipolarization, the front boundary of the reconnection outflow can also lead to a strong but localized magnetic dipolarization, named a reconnection front. The enhancement of the north-south magnetic component is usually adopted as the indicator of magnetic dipolarization. However, this field increase alone cannot distinguish between the two fundamentally different mechanisms. Using measurements from Cassini, we present multiple cases whereby we identify the two distinct types of dipolarization at Saturn. A comparison between Earth and Saturn provides new insight to revealing the energy dissipation in planetary magnetospheres.

Monday, June 12 – 12:00

A Multi-Instrument Study of Dipolarizations within the Kronian Magnetotail

Andrew Smith, Caitriona Jackman, Michelle Thomsen, Don Mitchell

* University of Southampton

Abstract

Reconnection is the fundamental physical process by which magnetic fields can reconfigure, in the course of which it transfers magnetic energy to the surrounding plasma. A spacecraft located planetward of a magnetotail reconnection site may observe a dipolarization front: the snapping back of magnetic field lines towards the planet. Dipolarizations have been identified in Cassini magnetometer data as significant (above background) north-to-south rotations of the magnetic field [e.g., Smith et al., 2016]. Three years of data were surveyed covering radial distances from 10-69 RS and local times from 18:00-06:00. Concurrent Cassini Plasma Spectrometer (CAPS) data were then analyzed to search for evidence of related electron heating. The distribution and recurrence of identifications across the Kronian magnetotail, as well as their plasma composition and front propagation direction were also examined.

Monday, June 12 – 12:15

Closed field line vortices and retrograde plasma motion in the nightside magnetosphere of Saturn

Zoltan Nemeth, Karoly Szego, Stanley W. H. Cowley

* Wigner Research Centre for Physics

Abstract

Recent results suggest that the characteristic length of plasmoids in the Kronian system is larger than that estimated earlier. The recurrence time of disconnection events are longer than the rotation period of the planet (45h vs. 10.6h at Saturn), which implies that the field lines observed at the nightside outer magnetosphere may be connected to the dayside hemisphere of the planet. We investigated the consequences of this low recurrence rate regarding azimuthal plasma motion and global magnetospheric structure. In one Kronian day the two footpoints of a field line rotate completely around the planet, while its middle point is fixed in the plasma sheet in the outer magnetosphere far away from the planet. Thus every point of the field line (its middle point being the sole exception) will perform some kind of rotating motion, and the dilute plasma of higher latitudes will move together with the field. We show that the resulting pattern is nearly identical to the usual co-rotation near the planet, but further downtail the field lines form vortices, and the plasma whirling around in these vortices never reaches the dayside. Here the azimuthal plasma motion is prograde at lower latitudes, but at high enough latitudes it is reversed. Using LANMOM ion moments derived from data measured by the CAPS instrument we tested this hypothesis and observed the retrograde plasma motion indicating plasma moving together with field lines connected to the dayside hemisphere of the planet.

Monday, June 12 – 14:00

Cassini observations of aperiodic waves on Saturn's equatorial current sheet

Carley J. Martin, Christopher S. Arridge

* Lancaster University

Abstract

Saturn's equatorial current sheet experiences many perturbations including, but not limited to, aperiodic waves. The Cassini magnetometer is used to identify these waves from equatorial revolutions of the spacecraft from 2005 – 2012. A model based on a Harris current sheet and deformed by a Gaussian pulse wave function is fitted to the magnetometer data. This facilitates the resolution of variables such as wave number, angular frequency, amplitude of the wave and scale height of the magnetic field. Once fitted we find that, statistically, the amplitude of the waves and scale height of the current sheet increase radially. We find a range of wavelengths from 100 m to 1000 m, and a median phase velocity of 0.25 Rs s-1. Using radial and azimuthal wave numbers, direction of propagation is resolvable using the model. This allows the origin of the waves to be estimated, such as the magnetopause movement causing compression as well as reconnection, interchange instabilities and other processes occurring in the magnetosphere of Saturn.

Monday, June 12 – 14:15

Survey of intense whistler-mode emissions in Saturn's magnetosheath

David Pisa, Ali H. Sulaiman, Ondrej Santolik, George B. Hospodarsky, William S. Kurth, Donald A. Gurnett

* Institute of Atmospheric Physics CAS, Prague, Czech Republic

Abstract

Intense whistler-mode emissions known as "lion-roars" have been already reported by many missions inside the terrestrial magnetosheath. Recently, we have reported the evidence of such emissions in Saturn's magnetosheath. We present a survey of these intense emissions as detected by the Cassini spacecraft between years 2004 and 2010. We identified eight time intervals with almost 37 hours of the intense lion-roar-like emissions in the low-band (up to 50 Hz) RPWS/WFR spectrogram. The emissions were observed across the day-side magnetosheath between magnetic local times from 0730 to 1600. The emissions were narrow-banded with a typical frequency up to 30 Hz, well below the local electron cyclotron frequency (100 – 1000 Hz). Using the minimum variance analysis method, we show that the waves are right hand circularly polarized and propagate at small wave normal angles (<40 degrees) with respect to the ambient magnetic field. Finally, we discuss the statistical properties of the lion-roar-like emissions at Saturn and compare them to observations at Earth.

Monday, June 12 – 14:30

The Impact of Saturn's Non-axisymmetric Magnetosphere on the Solar Wind Flow

Ali H. Sulaiman, Xianzhe Jia, Nicholas Achilleos, Nick Sergis, Donald A. Gurnett, William S. Kurth

* University of Iowa

Abstract

The interaction between the solar wind and a magnetosphere is fundamental to the dynamics of a planetary system. Dayside magnetic reconnection is understood to be an important process driving the exchange of momentum and energy between the different regimes. The specific range of conditions under which this is permitted continues to be of active interest within the community. This problem extends to the outer planets where both the occurrence rate and locations of dayside reconnection remains an open question. Here we focus on the impact a non-axisymmetric magnetosphere has on the solar wind plasma that flows around it and in reconfiguring its upstream magnetic topology. We present evidence of deviation of the interplanetary magnetic field upstream of Saturn's polar-flattened magnetosphere using data from the Cassini spacecraft. With the aid of a global magnetohydrodynamic simulation, we show a significant asymmetry of the magnetosheath flow. The deviation of the magnetic field is attributed to preferential flow over the poles, driven by an asymmetric distribution of pressure gradients. We anticipate our results will provide a more accurate insight into the global conditions upstream of the rotationally-dominated outer planets.

Monday, June 12 – 14:45

A Novel Detection and Classification Method for Analysis of Interchange Injection Events at Saturn Using MIMI-CHEMS

Abigail Azari, Michael Liemohn, Xianzhe Jia, Nick Sergis, Abigail Rymer, Michelle Thomsen, Christopher Paranicas, Donald Mitchell, Jon Vandegriff

* University of Michigan - Climate and Space Sciences and Engineering

Abstract

The Cassini spacecraft has routinely observed interchange injection events with multiple instruments since arriving at Saturn in 2004. Interchange injection events are thought to initiate from a Rayleigh-Taylor like plasma instability sourced from Saturn's rapid rotation (period 10.8 hours) and the dense plasma population outgassing primarily from Enceladus. This results in injections of low density, highly energetic (keV) plasma from the outer reaches of the Saturn system closer to the planet.

Previous work has provided a statistical analysis of injections by Saturnian Longitude System (SLS), L–shell, and local time (Chen and Hill, 2008, Lai et al. 2016, Kennelly 2013). We will present an automated identification and classification method from CHarge Energy Mass Spectrometer (CHEMS) ion flux data. Our method has been trained and tested on the first two orbits of 2005 and shows good agreement with manual identification and previous survey results. The algorithm statistically identifies events by evaluating intensity by energy and radial dependence. Our method provides a unique opportunity to statistically classify events by severity. Our preliminary results from 2005-2006 show peak occurrence between 8-11 Saturn radii – in agreement with previous surveys.

We will present initial statistics of interchange injection events from 2005–2016 by local time and radial dependence, compare to previous studies, and we will consider results on the classification of event severity.

Monday, June 12 – 15:00

Cassini RPWS Dust Observation During the F-ring and Proximal Orbits

S. -Y. Ye, W. S. Kurth, G. B. Hospodarsky, A. M. Persoon, D. A. Gurnett, M. Morooka, J. -E. Wahlund, H. -W. Hsu, M. Seiss, R. Srama

* University of Iowa

Abstract

During the F-ring and proximal orbits of Cassini's grand finale, the spacecraft crosses the equatorial plane near the Janus/Epimetheus ring and between the D ring and atmosphere. These regions are populated with dust particles that can be detected by the Radio and Plasma Waves Science (RPWS) instrument via either the electric field antenna signal or the difference in electron and ion densities measured by the Langmuir probe. Analysis of the waveforms recorded by RPWS receivers can provide estimations of the density and size distribution of the dust particles. These measurements can be made regardless of the spacecraft attitude, for example, during the first proximal orbit when the high gain antenna is pointed to the ram direction. In the absence of waveform data, the power spectrum of the dust impact signals can also be used as a proxy for dust density. RPWS measurements are shown to be consistent with the data from the Cosmic Dust Analyzer (CDA), the dedicated dust instrument onboard Cassini. The in-situ measurements will help quantify the hazards posed to Cassini spacecraft during the proximal orbits.

Monday, June 12 – 15:15

Discovery of Protons between Saturn's F-Ring and G-Ring

Edward Sittler, Meredith Elrod, Robert Johnson, John Cooper, Wei-Lin Tseng, Todd Smith, Marcus Shappirio, David Simpson

* NASA Goddard Space Flight Center

Abstract

In analyzing the Cassini data between Saturn's A-ring outer edge and Mimas' L shell numerous inconsistencies have been reported in estimates of total ionic charge and electron density. Models not only predicted the presence of O+ and O2+ ions, but also protons and H2+ ions. Until now the protons and H2+ were not identified in the Cassini Plasma Spectrometer (CAPS) Ion Mass Spectrometer (IMS) data, although attempts had been made. A recent analysis of the IMS composition data, when its Linear Electric Field (LEF) post-acceleration voltage was at Vpa = 6000 V and not the usual Vpa =14600 V, has identified the presence of protons at least 15 sigma above the background noise. In the case of H+ the parameter x = sqrt(M/(Vpa + E/Q)) 1/vion (i.e., vion is the ion speed within the instrument's time-of-flight (TOF) sub-system) with E/Q 6 V which is used to organize the instrument's straight-through (ST) TOF calibration data quite well, is well within parameter regime of the IMS calibration data, and predicts the proton peak position within instrument uncertainties. The discovery was made using the Saturn Orbit Insertion (SOI) outbound data.

Monday, June 12 – 16:00

Temporal and spatial variations of energetic ions and electrons in the inner Saturnian magnetosphere: Results of the high-latitude Cassini orbits 2016-2017

Norbert Krupp, Elias Roussos, Peter Kollmann, Chris Paranicas, Donald G. Mitchell, Krishan Khurana

* Max Planck Institute for Solar System Research

Abstract

During the last phase of the Cassini mission (F-ring and Proximal Orbits) the spacecraft performs high-latitude orbits completing a scan of Saturn's magnetosphere from the inner edge of the radiation belts to the lobes and the magnetotail once every 6-7 days. Besides offering the opportunity to investigate systematically the electrons and ions in largely unexplored regions of the Saturnian radiation belts, the orbits allow to probe short time scales of variability and the immediate response of the radiation belts to changes in the magnetotail in great detail. We show results of the Low Energy Magnetospheric Measurement System (LEMMS), one of the sensors of the Magnetosphere Imaging Instrument (MIMI) onboard Cassini during those orbits. LEMMS measures electrons and ions in the keV to MeV energy range, separated in a number of energy channels. We present intensities and energy spectra of electrons, protons and heavier ions in the Saturnian radiation belts between 2 and 8 RS and show their temporal and spatial variations and discuss the factors controlling them.

Monday, June 12 – 16:15

Local effects on Saturn's Electron Radiation Belts by Z-mode, O-mode, Chorus and EMIC waves

Emma Woodfield, Richard Horne, Sarah Glauert, Doug Menietti, Yuri Shprits

* British Antarctic Survey

Abstract

Wave particle interactions have been shown to be crucial in the dynamics of Earth's electron radiation belts and more recently the importance of local acceleration of electrons by chorus waves at Jupiter has also been demonstrated. Here we discuss the effects of wave particle interactions on Saturn's electron radiation belts. Specifically we talk about the effects of Z-mode, O-mode, chorus and EMIC waves. We show that parallel propagating Z-mode waves are very effective at accelerating electrons inside of 4 Rs. Outside of 4 Rs chorus waves and EMIC are more prevalent with differing effects.

Monday, June 12 – 16:30

Saturn Ionosphere – as detected by the RPWS during the proximal orbits

J.-E. Wahlund, W. M. Farrell, M. Morooka, D. Andrews, G. B. Hospdarsky, W. S. Kurth, and S.-Y. Ye

* Swedish Institute of Space Physics

Abstract

In late April 2017 Cassini started its "Grand Finale" by flying in between the innermost D-ring and Saturn's atmosphere. We will report Radio & Plasma Wave Science (RPWS) data from the first few of these orbits. The topside ionosphere of Saturn was clearly measured, as the plasma density increased (up to 2000 cm-3) and became cold (below 0.1 eV) toward closest approach (near 3000 km altitude, or 63000 km distance from the planet's center). The profile is a cut in latitude and altitude, where the ring shadow effect (with less solar EUV ionizing radiation) could be identified in the south hemisphere and reflecting the ring structure. The big surprises were the large variability from orbit to orbit of almost an order of magnitude in density, a decrease of the electron density near the equatorial plane, and detailed ionosphere structures at corresponding L-values in the north and south hemispheres. We discuss our results in terms of the interaction with the rings.

Monday, June 12 – 16:45

The Saturnian near-ring plasma environment

Wei-Ling Tseng, Robert E. Johnson, Meredith K. Elrod, O. J. Tucker, Wing-Huen Ip

* Department of Earth Sciences, National Taiwan Normal University

Abstract

Saturn's ring atmosphere is primarily generated by photolytic decomposition of water ice producing O2 and H2 (Johnson et al., 2006). Tseng et al. (2010) also predicted seasonal variations in the ring atmosphere and ionosphere due to the orientation of the ring plane to the sun. The ring atmosphere and ionosphere play an important role in the coupling dynamics between the main rings and the Saturnian system. First, they are the sources of neutrals (i.e., O2, H2, H; Tseng et al., 2013a) and plasma (i.e., O2+ and H2+; Tseng et al., 2011) in the Saturnian magnetosphere. Second, the main rings have strong interaction with Saturn's atmosphere and ionosphere (i.e., a source of oxygen into Saturn's upper atmosphere and/or the "ring rain" in O'Donoghue et al., 2013). Furthermore, Cassini CAPS data showed time variations in the complex plasma environment between the main rings and Enceladus (Elrod et al., 2012; 2014). The plasma environment in this interesting region is complicated by the neutrals from both the seasonally dependent ring atmosphere and Enceladus torus (Tseng et al., 2013b), and, possibly, from small grains from the main and tenuous F and G rings (Johnson et al.2017) and the Enceladus plumes (Hill et al., 2012) which produce the extended E-ring (e.g., Kempf et al., 2010). The data now coming in from Cassini's F-ring orbits should shed light on the dominant physics and chemistry in this region of Saturn's magnetosphere.

A Diffusive Equilibrium Model for the Plasma Density from 2.5 to 10 R_S

A. M. Persoon, D. A. Gurnett, W. S. Kurth, J. B. Faden, J. B. Groene, A. H. Sulaiman, S.-Y. Ye, M. Morooka, and J.-E. Wahlund

* University of Iowa

Abstract

Electron density measurements have been obtained by the Cassini Radio and Plasma Wave Science (RPWS) instrument covering a period from 30 June 2004 to 19 April 2017, including the recent density measurements from the F ring orbits. Near the F ring, densities are derived from electron plasma oscillations at high latitudes. At low latitudes, the densities are derived from an analysis of the QTN resonances, from ringing signatures due to dust impacts and from the Langmuir Probe sweep data. Beyond the F ring orbits, the densities are derived from RPWS measurements of the upper hybrid resonance frequency. The density measurements span latitudes up to 35 degrees and L values from 2.5 to 10. The electron density measurements are combined with ion anisotropy measurements from the Cassini Plasma Spectrometer (CAPS) and electron temperature measurements from RPWS and CAPS/ELS to develop a diffusive equilibrium model for a two-species plasma consisting of water group and hydrogen ions and thermal electrons in Saturn's inner magnetosphere. Density contour plots for the three plasma components are presented.

Monday, June 12 – 17:15

Dusty Plasma observation of Saturn's faint rings by Cassini/RPWS/LP

M. W. Morooka, J.-E. Wahlund, D. Andrews, A. Persoon, S.-Y. Ye, W. S. Kurth, M. K. Holmberg

* Swedish Institute of Space Physics, Uppsala

Abstract

It has been confirmed previously in the E Ring and near the Enceladus plume that nm to µm dust grains play an important role in the plasma as a negative charge carrier; it is a dusty plasma. Cassini have carried out many observations in the E ring and the G ring. From December 2016, during the Ring Grazing and Grand Final orbits, Cassini also crosses the equator of Saturn magnetosphere near the F ring and the D ring, respectively. All these rings consist mainly of small sized dust grains of the order of µm and less. We will show the electron and ion density measurements from the Langmuir probe onboard Cassini (RPWS/LP). During the F Ring crossings LP data showed significant charge differences between the electrons and the positive ions. They were associated with the dust impact observations of µm sized grains, which are a part of the carrier of the negative charges that LP measured. A comparison between the charged dust density estimated by the LP data and the µm dust density from the dust impact observation shows a variation of the dust grain size distribution during the ring crossing. The charge density ratio of the electrons to ions is variable from orbit to orbit, indicating a spatial variation of the dusty plasma characteristics of the rings or the time variability over weeks. We will show the ion and the electron densities near the E, G, F, and D rings and discuss the charge balance in the vicinity of Saturn's rings in terms of the characteristics of negative grains.

Tuesday, June 13 – 09:00

Cassini Grand Finale : new insights on the emission region and periodicities of Saturn Kilometric Radiation

Laurent Lamy, Philippe Zarka, Baptiste Cecconi, Bill Kurth, George Hospodarsky

* Observatoire de Paris

Abstract

The Cassini final polar passes consist of 20 F-ring orbits and 22 proximal orbits which are unique opportunities to sample in situ the kronian auroral region region twice per orbit. We present an overview of Cassini/RPWS measurements within or close to the sources of Saturnian Kilometric Radiation (SKR) identified so far to update our current knowledge on them, which relies on 2 isolated passes within SKR southern sources in 2008. We also take advantage of continuous remote observations at high latitudes to derive updated SKR periodicities in both hemispheres up to the northern solstice, where the solar illumination on the northern auroral region will culminate.

Tuesday, June 13 – 09:15

Planetary period oscillations in Saturn's magnetosphere

Stanley W H Cowley and G Provan

* University of Leicester

Abstract

One of the principal findings of the Cassini mission has been the ubiquitous presence of modulations near the planetary rotation period in essentially all magnetospheric parameters in the Saturn system. We review the present state of knowledge based on 14 years of Cassini observations, bringing the story up to date with the latest data.

Tuesday, June 13 – 09:35

Tracking the evolution of rotating features in Saturn's magnetosphere using imagery from Cassini's UVIS, VIMS, and INCA.

Joe Kinrade, Sarah Badman, Rebecca Gray, Chris Paranicas, Bill Kurth, Donald Mitchell, Kevin Baines, Wayne Pryor, Henrik Melin, Tom Stallard

* Lancaster University

Abstract

On day 99 of 2014, Cassini auroral imagery from UVIS and VIMS captured an active and structured dawn sector, indicating injection activity prior to and during the 9 hr imaging sequence (0800-1700 UT). Here we track a clear intensification signature that activated at dawn, rotated through noon and further intensified in both FUV and infrared emissions. The signature appeared poleward of the main emission boundary, and moved equatorwards as it rotated towards noon, indicating that the related magnetospheric plasma source population was moving inward and possibly related to reconnection return flow from the nightside magnetotail. Coincident imagery from the INCA camera clearly shows a rotating region of Energetic Neutral Atom (ENA) flux that, like the auroral signature, appeared at dawn, rotated to noon and brightened. The UVIS images also show clear bifurcations of the main emission post-noon, features that have been linked with magnetopause reconnection, possibly enhanced during magnetospheric compression by the solar wind. We compare the spatial and temporal extents of the rotating features in both the auroral and ENA images to reveal any possible physical link between them.

Tuesday, June 13 – 09:50

Global Scale Periodic Responses in Saturn's Magnetosphere

Xianzhe Jia, Margaret Kivelson

* University of Michigan, Ann Arbor, USA

Abstract

Despite having an axisymmetric internal magnetic field, Saturn's magnetosphere exhibits periodic modulations in a variety of magnetospheric properties at periods close to the planetary rotation period. While the source of the periodicity remains unknown, it is evident from Cassini observations that much of Saturn's magnetospheric structure and dynamics is dominated by global-scale responses to the driving source of the periodicity. We have developed a global MHD model in which a rotating field-aligned current system is introduced by imposing vortical flows in the high-latitude ionosphere in order to simulate the magnetospheric periodicities. The model has been utilized to quantitatively characterize various periodic responses in the magnetosphere, such as the displacement of the magnetopause and bow shock and flapping of the tail plasma sheet, all of which show quantitative agreement with Cassini observations. One of our model predictions is periodic release of plasmoids in the tail that occurs preferentially in the midnight-to-dawn local time sector during each rotation cycle. Here we present detailed analysis of the periodic responses seen in our simulations with focus on the properties of plasmoids predicted by the model including their spatial distribution, occurrence rate, and mass loss rate. We will compare these modeled parameters with published Cassini observations, and discuss their implications for interpreting in-situ measurements.

Tuesday, June 13 – 10:05

How are Planetary Period Oscillations Generated in Saturn's Magnetosphere?

Krishan K Khurana, Jonathan L. Mitchell, Ingo C. F. Mueller-Wodarg

* Dept. Earth, Planetary and Space Science, UCLA, CA 90095. USA.

Abstract

A distinguishing characteristic of Saturn's magnetosphere is the presence of spin-modulated periodicities in many field and plasma parameters even though Saturn's magnetic field is highly axisymmetric. Most of the observed periodicities are synchronized with the period observed in the amplitude of Saturn's intense radio waves called Saturn's Kilometric Radiation (SKR). The SKR emitted from the northern and the southern hemispheres have slightly different modulation periods. Many other magnetospheric parameters such as plasma density in the inner magnetosphere, magnetospheric ring current and the magnetotail current sheet are also known to be modulated at these periods. In this presentation, we resolve the mystery of how Saturn is able to modulate its kilometric wave radiation and many field and plasma parameters. By quantitatively modeling the amplitudes and phases of these oscillations in the magnetic field observed by the Cassini spacecraft, we show that the observed oscillations are the manifestations of two global convectional conveyor belts excited in Saturn's upper atmosphere by auroral heating below its northern and southern auroral belts. We demonstrate that a feedback process develops in Saturn system such that the magnetosphere expends energy to drive convection in Saturn's upper stratosphere but gains back an amplified share in the form of angular momentum that it uses to enforce corotation in the magnetosphere and power its aurorae and radio waves.

Tuesday, June 13 – 10:20

The observed effects of "ring rain" on the ionosphere of Saturn

James O'Donoghue, Luke Moore, Tom Stallard, Henrik Melin, Jack Connerney, Ron Oliversen

* NASA Goddard Space Flight Center

Abstract

In 2013, we discovered for the first time that through a low-latitude magnetosphere-ionosphere coupling, Saturn's rings leave an imprint on the planetary upper atmosphere. The data were obtained using the 10 meter Keck telescope in 2011, and we found that the upper atmosphere must be modified by an influx of water products (e.g. H2O+, H3O+, O+, etc.) which are transported from Saturn's rings via the innermost magnetosphere. Here we present the first re-detections of this "ring rain" at Saturn, using ground-based Keck telescope data from 2013 and 2014. We have found that the emission from low-latitudes decreases dramatically from 2011 to 2013/14, and that this drop in emissions is associated with a decreased upper atmospheric temperature. We also estimate temperatures and densities of H3+ as a function of latitude on Saturn for the first time, informing our understanding of how ring rain affects the ionosphere thermally and chemically. Temperature measurements allow us to investigate whether or not this ring-ionosphere coupling leads to the local heating of the upper atmosphere in a manner similar to the aurora. Density information allows us to approximate the quantity of water products transferred. This comes at a crucial time as the Cassini spacecraft is undergoing, and has performed, orbits between the planet and rings, and so is able to directly sample the material within the inner magnetosphere that causes ring rain.

Tuesday, June 13 – 11:10

Magnetosphere-Ionosphere Coupling at the Outer Planets

Emma Bunce

* University of Leicester

Abstract

Magnetic field measurements of the Galileo spacecraft have been interpreted as evidence for induction signals within a subsurface ocean at Callisto. Such signals are caused by induction currents within an electrical conductive shell driven by the periodic variation of Jupiter's magnetic field seen in the rest frame of Callisto. Galileo and Hubble Space Telescope observations have also shown that Callisto possesses a substantial atmosphere and, in particular, a conductive ionosphere. Here we revisit the question whether Callisto possesses a subsurface ocean. Therefore we develop a model that includes the plasma interaction of Jupiter's magnetospheric plasma and electromagnetic induction in Callisto's ionosphere. The conductivity structure of the ionosphere is derived from a model of Callisto's ionosphere by Hartkorn et al. (2017). Our results show that major parts of Callisto's observed magnetic field environment can be explained without inductions effects in a saline subsurface water ocean.

Tuesday, June 13 – 11:40

How are magnetospheric plasmas heated?

Margaret Galland Kivelson

* UCLA, Los Angeles, CA

Abstract

In a rigorous thermodynamic sense, thermal equilibrium implies isotropic velocity space distributions of Gaussian form but magnetospheric plasmas have loss cones that mess up isotropy and power law tails that depart from Gaussian forms. Ignoring such niceties, we integrate over velocity and equate the average energy per particle with the temperature of a plasma distribution. Thermodynamicians would cringe, but to most magnetospheric physicists, an increase of the average energy per particle measured in the system at rest relative to the bulk flow is regarded as heating. Magnetospheric plasmas gain energy both adiabatically and non-adiabatically. Adiabatic heating comes in different flavors. The first adiabatic invariant requires transverse energy to increase linearly with the magnetic field magnitude; the second adiabatic invariant implies parallel heating through Fermi acceleration as particles bounce along flux tubes shrinking in length. Typically, anisotropy increases with displacement. Non-adiabatic heating can arise through magnetic reconnection, diffusion, such as that connected with interchange instabilities, ionization of neutrals followed by ion pickup, and charge exchange between neutrals and ions. Wave-particle resonances can heat or cool a plasma. Inertial forces, rarely invoked in the terrestrial context, may become significant in rapidly rotating magnetospheres. These concepts will be discussed the magnetospheres of Jupiter and Saturn.

Tuesday, June 13 – 12:00

Comparisons of Radio and Plasma Wave Observations from Juno and Cassini in Their Similar Orbits at Jupiter and Saturn

W. S. Kurth, D. A. Gurnett, G. B. Hospdarsky, S. Ye, J. D. Menietti, A. M. Persoon, A. Sulaiman, M. Imai, S. Tetrick, P. Zarka, L. Lamy, B. Cecconi, C. Louis, A. Lecacheux, W. M. Farrell, G. Fischer, J.-E. Wahlund, M. Morooka, M. K. Dougherty, S. J. Bolton, J. E. P. Connerney, S. M. Levin, P. Louarn, P. Valek, B. H Mauk

* University of Iowa

Abstract

Cassini enters its "Grand Finale" orbits beginning in late April 2017 with perikrones between the atmosphere and the D ring. The orbit inclination is approximately 63° for both phases, hence, both are expected to take Cassini through the source regions of Saturn Kilometric Radiation (SKR). The Grand Finale orbits carry the spacecraft across magnetic field lines connecting the ring system with the planet. Juno is simultaneously orbiting Jupiter in similar orbits. Juno is in a 90° inclination orbit with perijove between Jupiter's atmosphere and its ring system. Juno has already skimmed through or close to Jupiter's auroral radio emission sources and provided in situ examples of the cyclotron maser instability in operation as well as observations of plasma waves of various types on auroral field lines. In addition, Juno has scanned, pole-to-pole, the very innermost region of Jupiter's magnetosphere, inviting comparisons of radio and plasma waves within the inner magnetospheres of these two giant planets. Observations of non-terrestrial in situ auroral radio generation are important in the study of the cyclotron maser instability (CMI) in different planetary settings, so such observations from both Juno and Cassini are of critical interest. Another exciting aspect of these orbits at both planets is the exploratory nature of observing plasma waves in a region not previously sampled with the possibility of investigating interactions between the rings and atmosphere.

Tuesday, June 13 – 12:15

Plasma Heating, Large-Scale Injections and Radio Emissions at Saturn, Jupiter and Earth: Conclusions from Cassini and Implications for JUICE Observations of Jupiter

Pontus C. Brandt, Donald G. Mitchell, Norbert Krupp, Joseph Westlake, Kostas Dialynas, Baptiste Cecconi, Kunihiro Keika

* The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA.

Abstract

Plasma is heated to super-coronal temperatures at Saturn, Jupiter and Earth. One of the underlying processes points to fast planet-ward flows of low-density bubbles, organized in large-scale injections. Low-frequency radio emissions display an intriguing correlation with such injections in all three of these planetary magnetospheres. We present Cassini observations of periodic large-scale injections revealed by global ENA imaging and ion measurements obtained by the Cassini/MIMI, to probe ion acceleration processes and their global consequences for heating and force-balance. We discuss the peculiar finding of very periodic injections at around 6 RS that appear to correlate with narrow-band emissions and precede large-scale injections beyond 12 RS that correlate with bursts of Saturn Kilometric Radiation. We contrast these phenomena to Galileo observations of quasi-period injections of fast flows at Jupiter, and the similar occurrences of Hectometric emissions preceded by narrow-band emissions. Terrestrial observations are used to detail similar fast flows, their consequence for force balance, and their high correlation with the corresponding Auroral Kilometric Radiation. We discuss how these findings will guide the operations of the PEP/JENI ENA Camera on board the JUICE Mission. The commonalities between these three seemingly different systems are summarized with implications for the magnetospheric dynamics at Uranus, Neptune and Exoplanets.

Tuesday, June 13 – 14:00

The role of the solar wind for the outer planet magnetospheres

Peter Delamere

* University of Alaska Fairbanks

Abstract

Magnetospheric dawn/dusk asymmetries are, fundamentally, linked to the solar wind interaction. At Earth, the dominance of sunward, solar wind-driven flows via a Dungey cycle of reconnection leads to an asymmetric corotating plasmasphere contained within the magnetospheric cavity. Magnetospheric flows at Jupiter and Saturn, on the other hand, are dominated by corotation with the solar wind playing a minor role when adopting the terrestrial corotation/convection model. Nevertheless, Jupiter and Saturn exhibit significant dawn/dusk asymmetries. Following the New Horizons Jupiter flyby, the solar wind interaction at Jupiter and Saturn has been vigorously debated. Key aspects of this debate include large-scale magnetic reconnection vs. some unspecified tangential drag at the magnetopause boundary, generating a viscous-like interaction. Recent studies have demonstrated that the Kelvin Helmholtz instability causes tangential drag via intermittent and small-scale reconnection – a key component of mass, momentum, and energy transport at the magnetopause boundary. Burkholder et al., [2017] showed that reduced magnetosheath flows on Saturn's dawn flank are consistent significant momentum transport at the magnetopause boundary, confirming an active solar wind interaction. This tutorial presentation will present a broad overview of the solar wind interaction at Jupiter and Saturn, including different perspectives from data (including Juno observations), theory, and modeling.

Tuesday, June 13 – 14:30

The Evidence for Solar Wind Control of Auroral Processes at Jupiter and Saturn

John Clarke

* Boston University

Abstract

There have now been a series of observations of Jupiter and Saturn tied either to nearby measurements of the solar wind or extrapolations from the Earth. The data show clear evidence for auroral brightenings that are correlated with the arrival of solar wind shocks, with a strong correlation for Saturn and occasional correlation at Jupiter. How should we interpret these data? Why is there a high degree of correlation at Saturn and only some correlated events at Jupiter? What is the most important controlling parameter in the solar wind? Correlations have been demonstrated for solar wind dynamic pressure, but this is easier to extrapolate than interplanetary magnetic field, and shock fronts are normally accompanied by large changes in the IMF. These questions will be discussed in view of our knowledge of the different conditions in the magnetospheres of Jupiter and Saturn.

Tuesday, June 13 – 14:45

Diurnal And Seasonal Variability of Uranus' Magnetosphere

Xin Cao, Carol Paty

* Georgia Institute of Technology

Abstract

The interaction between Uranus' intrinsic magnetic field and the solar wind is quite different from the magnetospheric interactions of other planets. Uranus' large obliquity, coupled with the fact that its dipole moment is off-centered and highly tilted relative to the rotation axis, leads to unique and seasonally dependent interaction geometries with the solar wind. We present results from adapting a multifluid MHD simulation to examine these seasonally dependent geometries in terms of the global magnetospheric structure, magnetopause and bow shock location, and magnetotail configuration. The Voyager 2 spacecraft encountered Uranus near solstice, and was able to observe the magnetic field structure and plasma characteristics of a twisted magnetotail [Behannon et al., 1987]. Auroral observations [Lamy et al.,2012] give some indication of the magnetospheric interaction with the solar wind. We use the magnetometer observations as a basis for benchmarking our simulations for the solstice scenario. We also demonstrate the structural difference of the magnetosphere between solstice and equinox seasons and the transition phase between solstice and equinox. The structure of Uranus' magnetosphere different seasons is quite distinct due to the orientation and rotation of the magnetic axis relative to the solar wind direction. We develop an analytical description of these boundaries based on the simulation to compare different seasons quantitatively.

Tuesday, June 13 – 15:00

Detection of the infrared aurora of Uranus

H. Melin, T. S. Stallard, L. N. Fletcher, R. E. Johnson, J. O'Donoghue, L. Moore, C. Tao

* University of Leicester

Abstract

The aurora of Uranus has only been observed a rare few times: by Voyager 2 and by the Hubble Space Telescope in the ultraviolet. At Jupiter and Saturn, observations of ground-based infrared H3+ emissions in the region of the magnetic poles has played an important role in advancing our understanding of the auroral process. Yet, at Uranus, no unambiguous detection of auroral H3+ emission has been made. Until now. We present NASA IRTF iSHELL observations from October 2016, which reveal highly localised emission at dawn, fixed in longitude. The intensity is driven by an increase in H3+ column density, rather than temperature, which is indicative of increased ionisation by auroral particle precipitation. This detection opens the doors for a full ground-based characterisation of Uranus' auroral morphology, thermospheric temperature, and ion wind structures in the upper atmosphere.

Tuesday, June 13 – 15:15

Comparing the Magnetospheres of Planets & Massive Stars

Matthew Shultz

* Uppsala University‘

Abstract

Over the past decade a sub-population of hot, massive stars has been discovered to have strong magnetic fields. Many of these magnetic hot stars host 'Centrifugal Magnetospheres' (CMs). CM host stars are typically rapidly rotating, with surface rotational velocities of hundreds of km/s. Their magnetic fields are in general strong (about 10 kG), simple (the majority are well-described by tilted dipoles), and stable (so-called fossil fields, rather than the dynamo fields seen in cool stars such as the Sun). Ions are provided by the star's radiatively driven wind, are confined by its magnetic field, and supported against gravitational infall by centrifugal force. While CMs have some important differences with planetary magnetospheres, there are also numerous similarities. By comparing and contrasting stellar and planetary magnetospheres, I will describe the observational diagnostics used to probe CM properties, and explore the current state of our theoretical understanding, with an emphasis on the open question of the mass leakage mechanism responsible for evacuating plasma from CMs.

Wednesday, June 14 – 09:00

Early Results from the Juno Mission

Scott Bolton, Jack Connerney, Steve Levin and the Juno Science Team

* Southwest Research Institute

Abstract

Juno is the first mission to investigate Jupiter using a close polar orbit. The Juno science goals include the study of Jupiter interior composition and structure, deep atmosphere and its polar magnetosphere. All orbits have perijove at approximately 5000 km above Jupiter's visible cloud tops. The payload consists of a set of microwave antennas for deep sounding, magnetometers, gravity radio science, low and high energy charged particle detectors, plasma wave antennas, ultraviolet imaging spectrograph, infrared imager and spectrometer and a visible camera. The Juno mission design, an overview of the early science results from Juno with an emphasis on results related to the magnetosphere, and a description of the collaborative Earth based campaign will be presented.

Wednesday, June 14 – 09:20

An Overview of Juno-UVS Observations of Jupiter's Auroras through Perijove 6

G. R. Gladstone, M. H. Versteeg, T. K. Greathouse, V. Hue, J. A. Kammer, J.-C. Gérard, D. Grodent, B. Bonfond, S. J. Bolton, J. E. P. Connerney, S. M. Levin, A. Adriani, W. S. Kurth, B. H. Mauk, P. Valek, D. J. McComas, G. S. Orton, and F. Bagenal

* Southwest Research Institute

Abstract

Currently, Juno's Ultraviolet Spectrograph (UVS) has observed the Jovian aurora during five perijove passes. On each pass, UVS observes Jupiter for 10 hours centered on closest approach in a series of swaths, with one swath per 30s spin of the Juno spacecraft. During this time the range to the aurora drops from 6 RJ to 0.3 RJ or less in the north (and reverses this in the south), so that spatial resolution and coverage change dramatically. The UVS scan mirror is used to target different features, as the auroral regions are generally much larger than UVS's 7-degree long slit can accommodate in a single swath. Typically, the scan mirror position is changed every 2 -5 Juno spins, to track specific targets or just raster across the entire auroral region. Since UVS only observes any particular location for 17 ms/swath, the series of swaths provide snapshots of ultraviolet auroral brightness and color. A variety of forms and activity levels are represented in this data set, and many have been described before with HST observations, but are seen here with higher spatial resolution. One interesting result is that in false color images (where RGB colors are assigned to long, medium, and short UV wavelengths, respectively), the emission morphology often alternates red and blue, in a way similar to patterns expected of large scale current systems. Further results which emerge as the UVS data are compared with data from the other Juno auroral instruments will also be presented.

Wednesday, June 14 – 09:35

Energetic particle measurements at Jupiter by the Juno-JEDI instrument

George Clark, B. H. Mauk, D. K. Haggerty, C. P. Paranicas, P. Kollmann, A. M. Rymer, S. Bolton, E. J. Bunce, S.W.H Cowley, S. Levin, A. Adriani, F. Allegrini, F. Bagenal, J. E. P. Connerney, R.W. Ebert, G. R. Gladstone, T. Kimura, W. S. Kurth, D. J. McComas, D. Ranquist, J. Saur, J. R. Szalay, and P. W. Valek

* Johns Hopkins University Applied Physics Laboratory

Abstract

As of March 2017, the Juno spacecraft has completed four 53.5 day Jovian polar orbits, with complete science coverage, with an apojove 110 RJ and a perijove 1.1 RJ. Thus far, the Jupiter Energetic particle Detector Instrument (JEDI) has been returning a rich and diverse data set that is already challenging our preconceived notions of Jupiter's magnetosphere and ionosphere. In this talk we will give a brief overview on the recent discoveries made by the JEDI instrument and the unresolved questions that are starting to emerge from the analysis. Specifically, we will briefly discuss Jupiter's radiation belts, distant plasma sheet observations and the coordinated observations between JEDI, Hisaki and HST. However, a significant portion of this presentation will be dedicated to energetic ion and electron observations over the polar auroral region. These energetic particle populations are observed to have peaked energy distributions consistent with the idea of local acceleration regions containing strong parallel electric fields. The particle phase space spectra suggest the potential drops vary between 100s of kV to 1 MV. We explore the origin of these strong potential drops within the downward current region by investigating their current-voltage relationship and comparing them to the current theoretical framework on Jovian MI-coupling.

Wednesday, June 14 – 09:55

Plasma Observations in Jupiter's Polar Magnetosphere from the Jovian Auroral Distributions Experiment (JADE)

R. W. Ebert, P. W. Valek, F. Allegrini, F. Bagenal, S. J. Bolton, J. E. P. Connerney, T. K. Kim, S. Levin, P. Louarn, C. E. Loeffler, D. J. McComas, C. Pollock, D. Ranquist, M. Reno, J. R. Szalay, M. F. Thomsen, S. Weidner, R. J. Wilson, and J. L. Zink

* Southwest Research Institute

Abstract

Juno crossed Jupiter's bow shock on 24 June, 2016 at 128 Jovian radii. The spacecraft proceeded to traverse Jupiter's dawn magnetosphere before being inserted into a 53-day polar orbit around Jupiter on 5 July, 2016. The first science perijove (PJ1) occurred on 27 August, 2016, providing the first opportunity to make in situ measurements of Jupiter's polar magnetosphere while remotely observing Jupiter's aurora. Observations of the plasma environment were obtained by the Jovian Auroral Distributions Experiment (JADE; McComas et al. 2013). JADE is a suite of plasma sensors consisting of one ion sensor (JADE-I) and two nearly identical electron sensors (JADE-E) that are designed to measure 0.01 to 46 kilo-electron volts per charge (keV/q) ions with masses $<$ 64 amu/q and 0.1 – 100 keV electrons, including their pitch angle distributions with up to 1 s resolution. In this presentation, we highlight observations from JADE during PJ1 and subsequent perijoves (PJ3, PJ4, PJ5). JADE observations during these perijove passes provided a wealth of new information on the plasma environment in Jupiter's polar magnetosphere including mono- and bi-directional field aligned electron beams and loss cone features, low-energy ($<$100 eV) protons, and heavy ions that magnetically map to the Io plasma torus and Jupiter's plasma sheet. We provide an overview of these observations and briefly discuss their implications for our understanding of Jupiter's magnetosphere.

Wednesday, June 14 – 10:15

Juno Magnetometer observations in the Jovian magnetosphere

Jack Connerney, Ronald J Oliversen, Jared R Espley, Daniel J Gershman, Jacob R Gruesbeck, Stavros Kotsiaros, Gina A DiBraccio, John L Joergensen, Peter S Joergensen, Jose M G Merayo, Troelz Denver, Mathias Benn, Jonas B Bjarno, Anastasia Malinnikova, Jeremy Bloxham, Kimberly M Moore, Scott J Bolton, Steven M Levin

* NASA Goddard Space Flight Center

Abstract

Juno entered polar orbit about Jupiter on July 4, 2016 to conduct the first exploration of the polar magnetosphere. The 53.5-day orbit trajectory carries Juno's science instruments from pole to pole in 2 hours, with periJove at 1.06 Rj from Jupiter's center, just above the clouds. Repeated passes will encircle the planet equally spaced in longitude ($<$12° at equator) to image Jupiter's dynamo. A number of such passes are required to bring the magnetic field into focus. MAG is equipped with two magnetometer sensor suites, 10 & 12 m from the center of the s/c at the end of one of Juno's three solar panel wings. Each contains a vector fluxgate magnetometer (FGM) sensor and a pair of co-located non-magnetic star tracker camera heads, providing accurate attitude determination for the FGM sensors. We present an overview of the magnetometer observations obtained during the first few polar orbits in context with prior observations and those acquired by Juno's other science instruments.

Juno spacecraft observations of plasma wave emissions in Jupiter's low-altitude polar regions

S. S. Tetrick, D. A. Gurnett, W. S. Kurth, M. Imai, G. B. Hospodarsky, S. J. Bolton, J. E. P. Connerney, S. M. Levin, and B. H. Mauk

* University of Iowa, Iowa City, IA, 52242, USA

Abstract

The Juno spacecraft arrived at Jupiter on July 5, 2016 and has made three successful passes over the high latitude regions of Jupiter. During each pass, the Juno Waves instrument detected broadband plasma wave emissions. The characteristics of the emission on 27 August 2016 was extensively studied [Tetrick et al., Geophys. Res. Lett., 2017]. This emission has been compared to similar emissions seen on the other two passes. For all three passes, the electron cyclotron frequency is much higher than the observed emissions. Both the E/cB ratios and the characteristic funnel-shape of the emissions are indicative of whistler-mode wave propagation. Frequency-dependent spin modulation phase shifts also indicate wave propagation up to the local plasma frequency. All three passes show correlation of the electric field spectral density data with fluxes of up-going electron beams observed by the Jupiter Energetic particle Detector Instrument (JEDI). The correlation coefficients range from 0.32 to 0.72, indicative of significant correlations. Evidence supporting whistler-mode propagation driven by energetic up-going electron beams has been found for all three passes. We believe that the observed emissions are propagating in the whistler-mode and are generated by up-going electron beams, which are ultimately caused by a coherent plasma instability.

Wednesday, June 14 – 11:15

Particle energization and structuring of Jupiter's main auroral oval as diagnosed with Juno measurements of (>30 keV) energetic particles

Barry Mauk, Dennis Haggerty, Chris Paranicas, George Clark, Peter Kollmann, Abi Rymer, Scott Bolton, Steve Levin, Alberto Adriani, Frederic Allegrini, Fran Bagenal, Bertrand Bonfond, Jack Connerney, Rob Ebert, Randy Gladstone, Denis Grodent, Bill Kurth, Dave McComas, Drake Ranquist, Jamey Szalay, Sadie Tetrick, Phil Valek

* The Johns Hopkins Applied Physics Laboratory

Abstract

Juno polar low-altitude energetic particle observations indicate that the most intense emissions from Jupiter's main auroral oval are caused by the impingement onto the atmosphere of relatively flat, energy-monotonic electron distributions, often extending to energies >1 MeV. They can be associated with bi-directional angular beaming with upward fluxes greater than the downward fluxes. Downward fluxes of >800 mW/m^2 have been observed. However, when viewed in high time resolution (1.0s) these distributions are sometimes (3 of 8)) intermixed with >50keV downward accelerated electron distributions with the classic inverted-V configuration, indicative of steady magnetic field-aligned electric fields. The highest downward energy peak observed so far is 400 keV. The inverted-V energy distributions lack the high energy tails observed in adjacent regions, and thus, contrary to what is observed at Earth, the associated downward energy fluxes are generally lower than the downward energy fluxes associated with the more intense energy-monotonic distributions. The relationship between these two modes of auroral particle energization is unclear. Do the classic auroral processes that create inverted-V distributions become so powerful that instabilities are stimulated that cause stochastic energization to turn on and dominate, or do these two different forms of auroral acceleration represent distinctly different processes? These and other questions are explored.

Wednesday, June 14 – 11:30

Observations of low energy plasma in Jupiter's sub-auroral magnetosphere

Philip Valek, Frederic Allegrini, F. Bagenal, S. Bolton, J. Connerney, R. W. Ebert, G. R. Gladstone, T. Kim, W. S. Kurth, S. Levin, P. Louarn, B. Mauk, D. J. McComas, Craig Pollock, D. Ranquist, M. Reno, J. R. Szalay, M. F. Thomsen, R. J. Wilson

* Southwest Research institute

Abstract

The Jovian Auroral Distributions Experiment (JADE) on the Juno mission measures plasma distributions using two nearly identical electron sensors and an ion sensor. The electron sensors (JADE-E) measure the electron distribution in the range of 100 eV to 100 keV and the ion sensor (JADE-I) measures the composition separated ion distributions in the range of 10 eV / q to 50 keV / q for ions with masses < 64 amu / q. The high velocity of the Juno spacecraft near perijove (50 km/s) allows observations of very low energy ions in the Spacecraft ram direction, down to below 1 eV/q. During the perijove passes when the spacecraft is at sub-auroral latitudes the ion observations show what are evidently two populations. The first appears to be of Iogenic origin based on its composition and velocity distribution. However, the second population appears to come directly from Jupiter itself. This population consists of low energy, light ions, largely consisting of protons. The ions have energies below 100 eV in the spacecraft frame, and extend down to the bottom of the JADE measurement range. In this study we will present observations of this second, low-energy, light ions in the sub-auroral regions and below an altitude of 1 Rj.

Wednesday, June 14 – 11:45

Electron measurements over Jupiter's Poles by the Jovian Auroral Distributions Experiment-Electrons (JADE-E) on Juno

Frederic Allegrini

* Southwest Research Institute

Abstract

The Jovian Auroral Distributions Experiment (JADE) on Juno provides critical in situ measurements of electrons and ions needed to understand the plasma distributions and processes that fill the Jovian magnetosphere and ultimately produce Jupiter's bright and dynamic aurora. JADE is an instrument suite that includes two essentially identical electron sensors (JADE-Es) and a single ion sensor (JADE-I). JADE-E measures electron energy distributions from 0.1 to 100 keV and provides detailed electron pitch-angle distributions at 7.5° resolution. During Juno's fifth science perijove, JADE was in its highest time resolution mode (1s) when the spacecraft crossed the field lines connected to the main oval four times in the northern hemisphere at different Jovicentric distances: 8.2, 4.5, 2.8, and 1.36 RJ. While these crossings occurred at different longitudes, this orbit geometry nevertheless allows us to investigate changes in electron energy and pitch angle distributions as a function of distance. In this presentation, we will highlight similarities and differences in the distributions for these consecutive crossings. We will also describe changes in the upward and downward beams and loss cones already observed during the first perijoves.

High Energy (>15 MeV) Particle Fluxes in Jupiter's Polar Regions

John Leif Jørgensen, Troelz Denver, Peter Siegbjørn Jørgensen, Jack Connerney

* Technical University of Denmark (DTU)

Abstract

The Juno Magnetometer Investigation consists of two vector magnetometer sensor suites, mounted 2m apart on a MAG boom outboard of solar array wing 1. Each is equipped with two star tracker attitude sensors, or Camera Head Units (CHUs), heavily shielded to function in a hostile radiation environment. Yet >15 MeV particles may penetrate to the CHU focal plane detector CCDs. Ionization signatures from these particles, routinely suppressed via software filters in the Advanced Stellar Compass (ASC) attitude determination algorithms, provide a direct measurement of the fluxes of such particles, as a function of time (every 125 ms) along Juno's trajectory. We present the measurement method, calibration, directional sensitivity and fluxes encountered during Juno's first five polar passages, and discuss particle signatures associated with trapped radiation, satellite footprints and aurora, and the numerous as yet unexplained local flux concentrations appearing along Juno's orbital trajectory.

Wednesday, June 14 – 12:15

Cyclotron maser mechanism at Jupiter: Juno observations

P. Louarn , F. Allegrini, D. J. McComas, P. W. Valek, W. S. Kurth, N.André, F. Bagenal, S. Bolton, J. Connerney, R. W. Ebert, M. Imai , S. Levin, J. R. Szalay, S. Weidner, R. J. Wilson

* IRAP/CNRS

Abstract

Using Juno plasma, wave and magnetic observations (JADE, Waves and MAG instruments), the generation mechanism of the jovian radio emission is analyzed. In the hectometric range (frequencies above 1 MHz, typically), it is shown that the pronounced loss-cones observed in the electron distributions may efficiently drive the cyclotron maser instability. The theory reveals that sufficient growth rates are obtained from the measured distribution functions, the free energy being associated with up-going electron populations at 5-10 keV and 10-30° pitch-angle. However, this scenario of loss-cone driven maser is likely not exclusive. Potential radio source regions characterized by localized increases of the particle fluxes have also been crossed, showing the possible formation of 'trapped' electron distributions. This would constitute another form of free energy that may be used by the maser process. In these regions, the radio wave generation could present similarities with the Earth scenario. The situation in the kilometric range (frequencies at 100 kHz and below) is more puzzling since the free energy for the maser appears difficult to identify

Wednesday, June 14 – 14:00

Magnetic Field Measurements and Derivation of Planetary Magnetic Field Models

J. E. P. Connerney

* NASA Goddard Space Flight Center

Abstract

We enter a new era of planetary exploration, with global mapping of magnetic fields overtaking the sparse observations provided by flybys of years past. The challenges associated with derivation of magnetic field models from flyby observations have been addressed with inverse methodologies designed to expose model non-uniqueness. Co-estimation now common in analyses of the Earth's magnetic field was essential in interpreting early flybys of Jupiter, where spacecraft on equatorial trajectories repeatedly transited the Jovian magnetodisc, a region filled with external ring currents. Models were further improved using field geometric constraints, the most fruitful of which being observations of the Io Flux Tube (IFT) footprint in Jupiter's ionosphere, north and south. These provide a kind of "ground truth" for planetary magnetic field models, requiring model field geometries to match that illuminated by the electromagnetic induction of orbiting satellites. Other field geometric constraints may be developed using particle absorption signatures, but these have been more limited in scope in application to the outer planets. Some magnetic field models seek to reconcile other observables – such as the frequency and beaming of radio emissions – with magnetic field models, based on explicit models of such phenomena. We'll try to sort through all the magnetic model monikers (VIP4, VIT4, VIPAL, etc.) and help you understand the differences.

Wednesday, June 14 – 14:30

Global Magnetohydrodynamic Simulations of Jupiter's Magnetosphere: Results on Global Configuration and Plasma Circulation

Yash Sarkango, Xianzhe Jia, Gábor Tóth, Kenneth C. Hansen

* University of Michigan, Ann Arbor

Abstract

Jupiter's inner magnetosphere contains sources of plasma associated with neutral escape from the Galilean moons. How this plasma is transported to the outer magnetosphere and subsequently lost to the solar wind remains an open question. In this study, we present results from global magnetohydrodynamic (MHD) simulations of Jupiter's magnetosphere in which we solve the semi-relativistic single-fluid ideal MHD equations in an extended 3D domain. Our model includes mass-loading as source and loss terms corresponding to a prescribed neutral torus distribution centered at Io's orbit, as well as the "wobbling" of the planetary magnetic field associated with the 10-degree dipole tilt. Results from our simulations are compared with plasma and field measurements from the Voyager and Galileo spacecraft, as well as previous theoretical and computational models. By including a realistic internal field, our simulation captures the periodic oscillation of the Jovian plasma sheet, which has been evidenced by in-situ measurements but whose three-dimensional large-scale structure is not well understood due to limited observations. Based on our simulations we determine the properties of plasmoids formed in the magnetotail, such as their spatial distribution and occurrence frequency, and their contribution to plasma loss from the magnetosphere. We also investigate the influence of the interplanetary magnetic field (IMF) on the large-scale structure of the magnetosphere.

Wednesday, June 14 – 14:45

Asymmetries in the Jovian magnetosphere

Emmanuel Chané, Joachim Saur

* University of Leuven (Belgium)

Abstract

Using three-dimensional global MHD simulations of Jupiter's magnetosphere, we study the influence of the solar wind on the system. We show that the interaction with the solar wind introduces many asymmetries: 1) day-night asymmetries, with field lines compressed on the day-side and elongated on the night-side, and 2) dawn-disk asymmetries with the plasma rotating faster at dawn, the current sheet being thicker at dusk, and the bend-back of the field lines being more important at dawn. These asymmetries are clearly visible even deep inside the magnetosphere and all these asymmetries are enhanced when the solar wind ram pressure is larger. Our simulations also show that the main auroral emission becomes brighter when the solar wind ram pressure is high. However, the precise response of the main emission depends on local time: it becomes brighter on the night-side, whereas on the day-side it first becomes slightly darker for a couple of hours, before also becoming brighter. The magnetosphere needs days to adapt to the new solar wind conditions. For example, the total electrical current closing in the ionosphere increases slowly during the simulation and it takes about 60h to reach a new equilibrium. By then the currents have increased by as much as 45%.

Thursday, June 15 – 09:00

Response of Jupiter's auroras to conditions in the interplanetary medium as measured by the Hubble Space Telescope and Juno

J. D. Nichols, S. V. Badman, F. Bagenal, S. J. Bolton, B. Bonfond, E. J. Bunce, J. T. Clarke, J. E. P. Connerney, S. W. H. Cowley, R. W. Ebert, M. Fujimoto, J.-C. Gérard, G. R. Gladstone, D. Grodent, T. Kimura, W. S. Kurth, B. H. Mauk, G. Murakami, D. J. McComas, G. S. Orton, A. Radioti, T. S. Stallard, C. Tao, P. W. Valek, R. J. Wilson, A. Yamazaki, I. Yoshikawa, ,

* University of Leicester

Abstract

We present the first comparison of Jupiter's auroral morphology with an extended, continuous and complete set of near-Jupiter interplanetary data, revealing the response of Jupiter's auroras to the interplanetary conditions. We show that for ∼1-3 days following compression region onset the planet's main emission brightened. A duskside poleward region also brightened during compressions, as well as during shallow rarefaction conditions at the start of the program. The power emitted from the noon active region did not exhibit dependence on any interplanetary parameter, though the morphology typically differed between rarefactions and compressions. The auroras equatorward of the main emission brightened over ∼10 days following an interval of increased volcanic activity on Io. These results show that the dependence of Jupiter's magnetosphere and auroras on the interplanetary conditions are more diverse than previously thought.

Thursday, June 15 – 09:20

Auroral explosion at Jupiter observed by the Hisaki satellite and Hubble Space Telescope during approaching phase of the Juno spacecraft

T. Kimura, J. D. Nichols, R. L. Gray, C. Tao, G. Murakami, A. Yamazaki, S. V. Badman, F. Tsuchiya, K. Yoshioka, H. Kita, D. Grodent, G. Clark, I. Yoshikawa, and M. Fujimoto

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Abstract

The continuous monitoring with the Hisaki satellite and Hubble Space Telescope (HST) discovered the transient auroral emission at Jupiter when the solar wind was relatively quiet, which would be associated with the disturbance that spans from the inner to outer magnetosphere. However, the temporal sequence of the magnetospheric disturbance is not resolved yet because we still lack the continuous monitoring. Here we report the coordinated observation made by Hisaki and HST in mid-2016. On day 142, Hisaki detected the onset of the transient aurora when the HST imaging was indicative of the large dawn storm. The outer emission followed the dawn storm within less than 20 hours. The Hisaki monitoring for the torus indicated that the hot plasma appeared in the torus during the transient aurora. These results imply that the disturbance is initiated at the outer/middle magnetosphere and rapidly expands toward the inner magnetosphere, accompanying the hot plasma injection at the torus.

Thursday, June 15 – 09:40

Revealing how the solar wind interacts with Jupiter's magnetosphere

Adam Masters

* Imperial College London

Abstract

The nature of the interaction between the solar wind and Jupiter's magnetosphere has been widely debated, yet remains poorly understood. Revealing how the magnetosphere is influenced by highly variable external solar wind conditions is essential for understanding energy flow within the system, and could potentially explain the mysterious polar aurora. Here we perform global modelling of conditions at the Jovian magnetopause using an approach that has been applied to all other giant planets, where different analytical descriptions of parameters (e.g., plasma density) are combined. The resulting maps of near-magnetopause conditions allow us to assess the operation of key processes at the boundary under the full range of solar wind and magnetospheric conditions. We predict the location of large-scale reconnection X-lines, the strength of the reconnection electric field, and the overall voltage applied to the system. We determine the regions of the interface that we expect to be unstable to growth of the Kelvin-Helmholtz (K-H) instability, and consider the motion of K-H perturbations (e.g., vortices). Future plans to combine this modelling with Galileo, Juno, and HST observations will be outlined.

Thursday, June 15 – 09:55

Juno, Hubble and James Webb observing Jupiter's aurora

Denis GRODENT, Bertrand BONFOND, Zhonghua YAO, Aikaterini RADIOTI, Jean-Claude GERARD, Benjamin PALMAERTS, Maïté DUMONT, G. Randall GLADSTONE, John T. CLARKE, Jonathan D. NICHOLS, Emma J. BUNCE, Lorenz ROTH, Joachim SAUR, Tomoki KIMURA, Glenn S. ORTON, Sarah V. BADMAN, Barry MAUK, John E. P. CONNERNEY, David J. McCOMAS, William S. KURTH, Alberto ADRIANI, Candice HANSEN

* Université de Liège, STAR Institute, LPAP

Abstract

Hubble Space Telescope (HST) observations of Jupiter's aurora, supporting the Juno mission, started on 30 Nov 2016. So far, they successfully covered orbits PJ03 to PJ06. After PJ07 in July 2017, the HST campaign will be interrupted by a solar avoidance period, preventing any observations from late August to the end of December 2017 (PJ08 to PJ10). The campaign will resume with PJ11 and continue until the end of HST cycle 25 (PJ15). Here, we present a brief summary of the HST data that has been acquired so far. It shows a broad range of auroral morphologies, suggesting that the Juno mission is sampling different facets of Jupiter's magnetospheric activity. One should keep in mind that HST will not last forever. We should be ready to switch to the James Webb Telescope and take advantage of the overlap between the HST and JWST missions to prepare a smooth transition. The numerous infrared observations of Jupiter's aurora obtained from ground based telescopes during Juno and obviously with Juno-JIRAM demonstrate that we can expect much from the tremendous performances of the JWST NIRCam and NIRSpec instruments.

Thursday, June 15 – 10:10

The Auroral Dynamic Duo - Jupiter's Independent Pulsating X-ray Hot Spots

William R. Dunn, Graziella Branduardi-Raymont, Licia Ray, Caitriona M. Jackman, Ralph P. Kraft, Ron F. Elsner, I. Jonathan Rae, Zhonghua. Yao, Marissa. F. Vogt, G. Randy Gladstone, Glenn S. Orton, James A. Sinclair, Peter G. Ford, Georgina A. Graham, Raquel Caro-Carretero, Andrew J. Coates, Geraint H. Jones

* UCL/MSSL

Abstract

Jupiter's Northern soft X-ray aurora is concentrated into a polar hot spot that is characterised by spectral lines of precipitating MeV ions [Gladstone et al. 2002; Elsner et al. 2005; Branduardi-Raymont et al. 2007]. These highly energetic emissions exhibit pulsations on timescales of several 10s of minutes and change morphology, intensity and precipitating particle populations with changing solar wind conditions [Dunn et al. 2016; Kimura et al. 2016]. This may be expected based on their location poleward of the main UV emission, in regions where magnetic field lines map [Vogt et al. 2015] to the noon-dusk outer magnetosphere and/or magnetopause [Kimura et al. 2016].

We present XMM-Newton and Chandra X-ray observations from Summer 2016 (during Juno approach) and Spring 2007 (during New Horizons approach), when the observing geometry provided good visibility of Jupiter's South Pole. These observations reveal that Jupiter's Northern and Southern X-ray aurora both appear to be concentrated into persistent hot spots. However, X-ray timing analysis suggests that, for these observations, Jupiter's Northern and Southern polar X-ray aurora behave independently.

We finish by outlining upcoming XMM-Newton X-ray campaigns and seeking feedback on how best to utilise the opportunities that the next few years offer, in order to understand precisely what drivers generate Jupiter's X-ray aurora and what the implications of this are for Jupiter's global magnetospheric dynamics.

Concurrent ultraviolet and infrared observations of the north Jovian aurora during Juno's first perijove

J.-C. Gérard, B. Bonfond, G.R. Gladstone, A. Adriani, A. Mura, D. Grodent, M. H. Versteeg, T. K. Greathouse, V. Hue, A. Radioti, F. Altieri, G. Sindoni, A. Migliorini, B.M. Dinelli, M.L. Moriconi, S.J. Bolton, J.E.P. Connerney, S.M. Levin, J.A. Kammer, F. Fabiano

* LPAP, STAR Institute, Université de Liège

Abstract

The UltraViolet Spectrograph (UVS) and the Jupiter InfraRed Auroral Mapper (JIRAM) observed the polar aurora during the perijove phase of the first Juno orbit (PJ1) on 27 August 2016. The UVS passband includes H2 bands that are directly excited by collisions of auroral electrons with H2. The JIRAM L-band imager includes some of the brightest H3+ features between 3.3 and 3.6 μm. The intensity if this IR emission depends on both the column density of H3+ and the temperature in the emitting region. A series of spatial scans obtained every 30 s is used to build up images of the polar regions. JIRAM's spatial resolution was about 100 km/pixel during most of the observations reported here while UVS has a substantially lower resolution (about 250 km/pixel). Concurrent observations were obtained during about 70 min in the north. We present a set of simultaneous ultraviolet and infrared images and point out similarities and differences in their morphology and brightness distribution. The time evolution in the two spectral domains will be described and interpreted in terms of energy of the auroral electrons, time history of the precipitation and lifetime of the H3+ ions. Ultraviolet color ratio maps visualize the spatial distribution of the characteristic energy of the primary auroral electrons. Other supporting information is provided by the H3+ temperatures and column density maps derived from the analysis of JIRAM spectra covering the 2-5 μm interval.

Thursday, June 15 – 11:15

Juno-UVS observation of the Io footprint during eclipse

V. Hue, G. R. Gladstone, T. K. Greathouse, M. Versteeg, J. Saur, M. W. Davis, B. Bonfond, D. C. Grodent, J.-C. Gérard

* Southwest Research Institute

Abstract

The Juno mission offers a unique opportunity to study Jupiter, from its inner structure to its magnetospheric environment. Juno-UVS is a UV spectrograph with a bandpass of $70<\lambda<205$ nm, designed to characterize Jupiter's UV emissions. One of the main feature of UVS is its scan mirror, which allows targeting specific UV features that are located +/- 30 $^{\circ}$ perpendicular to the Juno spin plane. Juno provides a unique vantage point in Jupiter's system to perform observations otherwise not possible from Earth. During Perijove 3 (PJ time: 11 December 2016 at 17:04 UTC), Io went into eclipse on Dec. 11th from 17:38:43 to 19:52:25 UTC. At that time, Juno was flying over the South Pole and observed the Io footprint from 17:50 to 22:04, with nearly continuous time coverage. Since Juno is spinning at 2 rpm, the Io footprint was observed once every 30 sec. The atmosphere of Io is mostly composed of SO2, with a small contribution of SO, S2, and NaCl. Whether its atmosphere is sublimation driven or supported by the volcanic activity is being controversially debated over decades. Studying the response of Io's footprint brightness as it enters and leaves eclipse provides a novel method to probe its atmospheric response to a diminution of the solar flux. We will present the observations of this event and how the interaction strength of the interaction between Io's ionosphere and the magnetosphere of Jupiter evolve during the eclipse.

Thursday, June 15 – 11:30

The shift of Ganymede's magnetic footprint under influence of plasma pressure anisotropy

Tatphicha Promfu, Jonathan Nichols, Suwicha Wannawichian, John Clarke

* National Astronomical Research Institute of Thailand, Thailand

Abstract

Ganymede is the third Galilean moon of Jupiter which is embedded in Jupiter's magnetosphere. The interaction between the magnetic field of Jupiter and the plasma around Ganymede causes an auroral magnetic footprint in Jupiter's ionosphere. This work presents a study of Ganymede's magnetic footprint based on FUV images of Jupiter obtained using the Hubble space Telescope (HST) Advanced Camera for Surveys (ACS) instrument. The magnetic mapping of Ganymede to the auroral region is determined from the colatitude of the moon's footprint, which we show varies with time. This is likely to be affected by the variation of Jupiter's magnetodisc field, which is influenced by the plasma in magnetosphere. In order to study the variation of the strength of the magnetodisc currents we consider the hot plasma pressure anisotropy by using magnetodisc model proposed by Nichols et al. (2015). The correlation between hot plasma pressure anisotropy and the magnetic field mapping of Ganymede's magnetic footprint due to the change of magnetic field lines in middle magnetosphere will be presented in this work. Furthermore, we compare the predicted colatitude of Ganymede's magnetic footprint from magnetodisc model with the direct observed data to find the condition of hot plasma pressure anisotropy which could control the shift of Ganymede's magnetic footprint.

Thursday, June 15 – 11:45

Plasma dynamics around Jupiter's inner magnetosphere deduced by EUV spectra of the Io plasma torus

Kazuo Yoshioka, Fuminori Tsuchiya, Masato Kagitani, Tomoki Kimura, Go Murakami, Fumiharu, Suzuki, Reina Hikida, Atsushi. Yamazaki, Ichiro. Yoshikawa, Masaki Fujimoto

* The University of Tokyo

Abstract

The EUV emissions from heavy ions in the Io plasma torus is observed by Hisaki, the Earth-orbiting satellite since end of 2013. The radial variation of plasma conditions (electron temperature and ion densities) are deduced through the spectral diagnosis method. The timescales of inward and outward transport of plasmas are also deduced using the physical-chemistry model. These motions may be the result of centrifugally-driven interchange instability (the cold dense plasmas from Io are transported to outward, and the depleted flux tubes which contain hot electrons are transported inwardly). In January 2015, there were large event of volcanic activity on Io. By comparing two data sets during volcanically quiet (November 2013) and active phases (February 2015), we found the drastic change of plasma motions. The velocity increased 2-4 times for both inward and outwards. They correspond to the increase of the neutral source rate caused by the volcanic activity.

Thursday, June 15 – 12:00

Jupiter's auroral ionospheric H3+ flows

Rosie E. Johnson, Tom S. Stallard, Henrik Melin, Jonathan D. Nichols and Stan W. H. Cowley

* University of Leicester

Abstract

We present a detailed study of the H3+ auroral emission at Jupiter, which uses data taken on the 31 December 2012 with the long-slit echelle spectrometer CRIRES (ESO-VLT). The entire northern auroral region was observed, providing a highly detailed view of ionospheric flows, which were mapped onto polar projections. Previous observations of ion flows in Jupiter's northern auroral ionosphere, using the long-slit echelle spectrometer CSHELL (NASA-IRTF) to measure the Doppler shifted H3+ $\nu 2$ Q(1,0-) line at 3.953 μm, showed a strongly sub-rotating region that was nearly-stationary in the inertial magnetic frame of reference, suggesting an interaction with the solar wind. In this work, we observe this stationary region coincident with a polar region with very weak infrared emission. Although our observations cannot determine the exact mechanisms of this coupling, the co-incidence between solar wind controlled ionospheric flows and a region with very low auroral brightness may provide new insights into the nature of the solar wind coupling. We also detected a super-rotating ionospheric flow measured at the narrow bright portion of the main auroral emission. The origin of this flow remains uncertain. Additionally, we detect a strong velocity sheer poleward of the peak in brightness of the main auroral emission. This is in agreement with past models which predict that conductivity, as well as velocity sheer, plays an important role in generating the main auroral emission.

Thursday, June 15 – 14:00

Radio emissions from Jupiter

Philippe Zarka

* Observatoire de Paris, CNRS, PSL

Abstract

I will try to place the recent results from Juno and ground-based decameter observations on the broader perspective of our present knowledge of Jupiter's low-frequency (kilometer to decameter wave) radio emissions. I will conclude with open questions.

Thursday, June 15 – 14:20

Source locations of Jupiter's decametric radio emissions measured by the modulation lane method

Kazumasa Imai, Charles A. Higgins, Masafumi Imai, Tracy Clarke

* Kochi National College of Technology

Abstract

Although there is a long history of Jupiter radio observations since the discovery in 1955, the emission mechanism of Jupiter's decametric radiation is not yet completely understood. The information of the radio source locations is a very important key to understand this emission mechanism. The modulation lanes in the dynamic spectra of Jupiter's decametric radio emissions were discovered by Riihimaa in 1968. We developed a model for the mechanism responsible for their production to provide a very close fit with the observations for the first time [Imai et al., 1992, 1997, 2002]. In this model, the slope of the modulation lanes provides important information to measure the radio source locations. By using the measured slope of modulation lanes it is possible to make precise calculations of the value of the lead angle based on Jupiter's magnetic field model. This lead angle is the angle between instantaneous Io's flux tube (IFT) and previously energized flux tube (PEFT) which corresponds to the real radio source locations. This remote sensing tool is called the modulation lane method [Imai et al., 1997, 2002, 2006]. Recently we are using this modulation lane method with data taken by the Long Wavelength Array Station 1 (LWA1). The high-sensitivity of the LWA1 allows us to measure source locations and beam parameters for many Io-related sources. In this analysis we found the existence of two independent radio sources in the case of Io-B and Io-C events.

Thursday, June 15 – 14:35

Io-Jupiter decametric arcs observed by Juno/Waves compared to ExPRES simulations

C. K. Louis, L. Lamy, P. Zarka, B. Cecconi, M. Imai, W.S. Kurth, G. Hospodarsky, S. L. G. Hess, X. Bonnin, S. Bolton, J. E. P. Connerney, S. M. Levin

* LESIA, Observatoire de Paris

Abstract

We compare observations from the Juno/Waves radio experiment with simulations of radio « arcs » in the time-frequency plane resulting from the Io-Jupiter interaction, performed with the ExPRES code. We identify the hemisphere of origin of the observed arcs directly from simulations, and confirm this identification through comparison with Juno, Nançay and Wind observations. The occurrence and shape of observed arcs are well modeled, at low latitudes with their usual shapes as seen from Earth, as well as at high latitudes with longer, bowl-shaped, arcs observed for the first time. Predicted emission is actually observed only when the radio beaming angle θ=(k,B)$\geq$70°±5°, providing new constraints on the generation of the decameter emission by the Cyclotron Maser Instability. Further improvements of ExPRES are outlined, that will then be applied to Juno and Earth-based observations of radio emissions induced by other Galilean satellites or associated to the main auroral oval.

Thursday, June 15 – 14:50

Statistical beaming properties of Jupiter's decametric radiation using the Juno Waves instrument

M. Imai, W. S. Kurth, G. B. Hospodarsky, S. J. Bolton, J. E. P. Connerney, S. M. Levin

* University of Iowa

Abstract

Due to complex interactions between Jupiter's plasma and magnetic field, the planet is a prolific source of radio and plasma waves in a broad range of wavelengths. From the polar region just above the Jovian auroras, the most intense radiation in decameter wavelengths (DAM) emanates in the frequency range of 1 to 40 MHz. There are two types of Jovian DAM radio bursts: Io-related components (Io-DAM) and non-Io-related components (non-Io-DAM). Because the appearance of Jovian non-Io DAM radio activity is sensitive to the latitude of the observer relative to Jupiter, it is important to monitor non-Io-DAM emissions over latitude in order to understand the form of the complex Jovian emission beam. The geometrical constraint of Earth observations and near-equatorial spacecraft has restricted such studies. Taking advantage of a broad Jovicentric latitudinal coverage from the Juno polar orbiter, we have investigated the Jovian non-Io-DAM radio beam by making occurrence probability and averaged intensity profiles of the radiation from the radio and plasma wave (Waves) instrument onboard Juno. The Juno Waves instrument is capable of recording the electric fields of waves from 50 Hz to 41 MHz from one electric dipole antenna, which covers the full spectra of Jupiter's radio bursts. Our statistical analysis gives a better understanding of the latitudinal beaming from Jupiter's polar regions.

Thursday, June 15 – 15:05

Evolution and morphology of Jupiter's auroral-related stratospheric heating

James Sinclair, Glenn Orton, Thomas Greathouse, Leigh Fletcher, Vincent Hue, Julianne Moses, Patrick Irwin, Henrik Melin, Rohini Giles

* Jet Propulsion Laboratory/Caltech

Abstract

Jupiter's northern and southern auroral regions exhibit elevated mid-infrared emission of CH4 at 7.8 μm, which indicates that auroral processes penetrate as deep as Jupiter's stratosphere and perturb the thermal structure. High-resolution measurements made by IRTF-TEXES in December 2014 and April 2016 show a puzzling evolution and morphology of stratospheric temperatures in Jupiter's northern and southern auroral regions. 1-mbar temperatures in the northern auroral region remained constant within uncertainty and localized within the northern auroral oval. However, 1-mbar temperatures in the southern auroral region exhibited a 10 K increase and the longitudinal orientation of the warmest 1-mbar temperatures in the southern auroral region moved west by 30° with no similar movement observed of the southern auroral ultraviolet and near-infrared emission. We continue to investigate this puzzling phenomenon: results from further TEXES measurements obtained on the IRTF in January and May 2017 and Gemini-North in March 2017 will be presented and compared with near-contemporaneous measurements from Juno's 5th and 6th perijoves.

Thursday, June 15 – 15:20

Jupiter's non-auroral ionosphere and magnetic equator

Tom Stallard, Angeline Burrell, Henrik Melin, Rosie Johnson, Steve Miller, James O'Donoghue, Luke Moore

* University of Leicester

Abstract

We present observations of complex structures within Jupiter's non-auroral ionosphere, including a ribbon of H3+ darkening that reveals the exact location of Jupiter's magnetic equator. Studies of Jupiter's non-auroral regions made twenty or more years ago, revealed Jupiter's equatorial ionosphere and thermosphere to vary in local time, latitude and longitude, both in UV and H3+ emission. However, the resolution of these studies was typically too low to detect small-scale variability. Similarly, current models based upon these observations can only see broader-scale changes in Jupiter's upper atmosphere.

We present the results of a series of recent studies, which have combined new large telescopes observations with re-analysis of past observing campaigns. These reveal, in detail, a wide variety of ionospheric features from mid-latitudes down to the equator. Some, such as the northern 'Great Cold Spot' appear to be thermospheric features driven by energy flow from the auroral regions. Others, in particular a dark ribbon near Jupiter's equator, are the result of the magnetic field's effects upon photoelectrons, as predicted by the JIM model, which allows us to map the location of Jupiter's magnetic equator for the first time. Many of these ionospheric features remain unexplained, but our current plans for further investigation will help reveal whether these are primarily driven by internal ionospheric processes or interaction with the magnetic field or neutral atmosphere.

Friday, June 16 – 09:00

Interactions of moon atmospheres and interiors with the giant planets' magnetospheres

Joachim Saur

* University of Cologne, Germany

Abstract

In our presentation we review basic physics of the electromagnetic interaction of the giant planet's moons with their surrounding magnetized plasmas. We also discuss implications on the existence of electrically conductive oceans within Jupiter's moons based on a reinterpretation of Galileo spacecraft measurements and Hubble Space Telescope observations of the moons auroral emissions. The large moons of the giant planets' are exposed to the time-variable flow of magnetized plasmas. The moons, their atmospheres and magnetic fields are thereby mechanical and electromagnetic obstacles to the flow of these magnetized plasmas. The flow past the obstacles causes momentum exchange, which is the root cause of the interaction. As a result large magnetic field and plasma perturbations are driven, which modify the plasma locally and which partially propagate away from the moons within Alfvén wings to produce auroral effects within the planets' atmospheres.
Time-variable magnetic fields also induce electric fields, which generate electric currents in subsurface oceans and in electrically conductive ionospheres. Observational constraints for these interactions come from in-situ plasma and field observations and from telescope observations of its auroral properties.

Friday, June 16 – 09:30

Kinetic simulations of Ganymede's magnetosphere and the formation of Ganymede's surface brightness asymmetries

S. Fatemi, A. R. Poppe, K. K. Khurana, M. Holmstrom

* University of California at Berkeley, CA

Abstract

Ganymede, the largest satellite of Jupiter and in the solar system, possesses strong surface brightness asymmetries both between its polar cap and equatorial regions and between its leading and trailing hemispheres. Here, we show that these asymmetries are due to differential Jovian plasma and energetic particle precipitation to the surface using a combination of a hybrid plasma model (kinetic ions and fluid electrons) and a particle tracing model. We describe the hybrid model, the first of its kind applied to Ganymede, and compare the results to both Galileo observations and previous MHD and MHD-EPIC models of Ganymede. We calculate spatially resolved precipitating Jovian ion fluxes to the surface of Ganymede for energies 1 keV $<$ E $<$ 10 MeV and find (1) precipitating fluxes peak near 100 keV and (2) excellent correlation between the precipitating flux and Ganymede's surface brightness variations. Thus, we conclude that precipitating energetic particle fluxes are the primary driver for altering the surface brightness of Ganymede.

Friday, June 16 – 09:45

A Comprehensive Picture of Callisto's Magnetic Environment during the Galileo Era

Lucas Liuzzo, Sven Simon, Moritz Feyerabend, Uwe Motschmann

* Georgia Institute of Technology

Abstract

We apply data analysis techniques and hybrid modeling to study Callisto's interaction with Jupiter's magnetosphere. Magnetometer data from the C3 and C9 Galileo flybys had been explained with a pure induction model, as the plasma interaction was weak. We expand this analysis to include the remaining five flybys (C10, C21, C22, C23, C30) where the plasma interaction was non-negligible. We therefore consider contributions to Callisto's magnetic environment generated by induction as well as the plasma interaction. We have identified a quasi-dipolar "core region" near Callisto's wakeside surface, dominated by induction and partially shielded from the plasma interaction. Outside of this region, Callisto's magnetic environment is characterized by field line draping. A rotational discontinuity where the field rotated by more than 50 deg separates the wakeside quasi-dipolar "core region" from the draping. Future flybys during the upcoming JUICE mission may sample the wakeside "core region" to better constrain the conductivity, thickness, and depth of Callisto's subsurface ocean. Our analysis also shows that even during a single flyby, various non-stationarities in the upstream environment may be present near Callisto, which may partially obscure the magnetic signature of the moon's subsurface ocean. Overall, our study provides a complete three-dimensional picture of Callisto's magnetic environment during the Galileo era, based on all available magnetometer data from the Galileo flybys.

Friday, June 16 – 10:00

Is there an ocean inside Callisto? Revisiting Galileo spacecraft magnetic field measurements.

Oliver Hartkorn, Joachim Saur

* Institute of Geophysics and Meteorology, University of Cologne

Abstract

Magnetic field measurements of the Galileo spacecraft have been interpreted as evidence for induction signals within a subsurface ocean at Callisto. Such signals are caused by induction currents within an electrical conductive shell driven by the periodic variation of Jupiter's magnetic field seen in the rest frame of Callisto. Galileo and Hubble Space Telescope observations have also shown that Callisto possesses a substantial atmosphere and, in particular, a conductive ionosphere. Here we revisit the question whether Callisto possesses a subsurface ocean. Therefore we develop a model that includes the plasma interaction of Jupiter's magnetospheric plasma and electromagnetic induction in Callisto's ionosphere. The conductivity structure of the ionosphere is derived from a model of Callisto's ionosphere by Hartkorn et al. (2017). Our results show that major parts of Callisto's observed magnetic field environment can be explained without inductions effects in a saline subsurface water ocean.

Friday, June 16 – 10:15

JUICE: A European Mission to Jupiter and its Icy Moons

Olivier Witasse, Stas Barabash, Pontus Brandt, Lorenzo Bruzzone,, Baptiste Cecconi, Michele Dougherty, Leigh Fletcher, Randy Gladstone, Olivier Grasset, Leonid Gurvits, Paul Hartogh, Hauke Hussmann, Luciano Iess, Ralf Jaumann, Yasumasa Kasaba, Yohai Kaspi, Norbert Krupp, Yves Langevin, Ingo Mueller-Wodarg, Pasquale Palumbo, Giuseppe Piccioni, Jeff Plaut, Hanna Rothkaehl, Ondrej Santolik, David Stevenson, Jan-Erik Wahlund, Peter Wurz, Adam Masters, Nicolas Altobelli, Claire Vallat, Christian Erd, Arnaud Boutonnet, Ignacio Tanco, Japeth Yates

* Olivier Witasse

Abstract

JUICE is the first large mission in the ESA Cosmic Vision program. The spacecraft will be launched in 2022, and will arrive at Jupiter in 2029. It will spend three years characterizing the Jovian system, the planet itself, its giant magnetosphere, and the icy moons Ganymede, Callisto and Europa. JUICE will then orbit Ganymede for almost a year. The main goal is to explore the emergence of habitable worlds around gas giants. The advanced instrumentation will permit new studies of Jupiter's magnetosphere and its interaction with the Galilean satellites, to further enhance our understanding of the evolution and dynamics of the Jovian system. The long-term magnetospheric science will push significantly beyond the capabilities of previous missions, and directly complement the results of the Juno mission. JUICE will explore Jupiter's magnetosphere covering a wide range of local times within the equatorial plane, as well as carrying out moderate excursions to higher latitudes. Three regions are of interest: the inner magnetosphere where the planetary magnetic field dominates, the middle magnetosphere where the effects of the magnetodisc controls the large-scale magnetic field and plasma populations, and the outer magnetosphere where the solar-wind effects are likely to be the largest. Remote sensing measurements of Jupiter's ring current and auroras will be provided, including, energetic neutral atom imaging. Magnetospheric parameters near the icy moons will be studied in detail.

Friday, June 16 – 11:00

The Alfven wings of Europa and Enceladus

Frank Crary, Aljona Bloecker, Sven Simon

* University of Colorado, Laboratory for Atmospheric and Space Physics

Abstract

We present analysis of magnetometer measurements from four encounters with Europa and Enceladus, the Galileo E25a Europa encounter, and the Cassini E8, E11, and E20 encounters. Magnetic field data from these encounters have received relatively little attention since they were distant encounters, ranging from 5.5 to 11 body radii from the satellite. However, all were polar encounters and either crossed or passed close to the Alfven wing. This is a very similar geometry to the Voyager 1 Io encounter. As a result, the observations are in the far field, and the magnetic field perturbations are attributable to the Alfven mode, rather than the fast or slow modes. (Although there are weak compressional signatures on the E8 and E11 encounters, which were south of the satellite and closer to the plume than the satellite itself.) This allows us to fit the data with a simple, analytic solution, just as was done for the Voyager 1 Io encounter [Acuna et al., 1981.] The more sophisticated modeling required for close flybys is not amenable to a formal chi^2 minimization to determine the magnitude of the currents in the Alfven wing. The result, a moment of the currents, can be used to estimate the total current, the conductivity of the ionosphere/plume, the degree of slowing within the flux tube, and the power transmitted towards high latitudes (e.g. to generate aurora at the foot of the flux tube.)

Friday, June 16 – 11:15

Sputtering of Large Organic Molecules from Satellites in Planetary Magnetospheres: Modeling Based on Laboratory Studies at Uppsala

Robert E Johnson , B.U.R Sundqvist

* University of Virginia

Abstract

Inspired by attempts to analyze bio-molecular materials for medical research, a group of nuclear physicist at Uppsala, lead by B.U.R. Sundqvist, who eventually became Vice Chancellor of Uppsala Univeristy, applied their fast counting and sensitive ion detection techniques to the study radiation-induced sputtering of biomolecules from surfaces, eventually developing practical medical instruments. After initiating these studies, they realized that the sputtering/desorption processes they observed were related to those driving the sputtering of whole molecules from low-temperature icy surfaces by W.L. Brown, L.J. Lanzerotti and colleagues at AT&T Bell Laboratories. These separate efforts were brought together at an international conference in Uppsala in 1980, which resulted in an enormous expansion of interest in this work both medically and for space physics. With the planning of new missions to study a critical astrobiology target, Europe, there is renewed interest in the possibility of detecting organic molecules sputtered from its surface by the impacting energetic heavy ions trapped in Jupiter's magnetosphere. In this talk, we will review the importance of the early work at Uppsala, as well as the significant amount laboratory work since then. We will use that to give new estimates of the ejection into the gas-phase of trace organic species embedded in an ice matrix on Europa's surface and, possibly, detected during a fly by mission remotely or by direct collections.

Are the Enceladus Plumes a Hotbed of Negativity?

Abigail Rymer, Ann Persoon, Michiko Morooka, Andrew Coates, Donald G. Mitchell, Shengyi Ye, Mark Perry

* JHU-APL

Abstract

The well documented Enceladus plumes create a dusty, asymmetric exosphere in which electrons can attach to small ice particles - forming anions, negatively charged nanograins and dust - to the extent that cations can be the lightest charged particles present and, as a result, the dominant current carriers. Several instruments on the Cassini spacecraft are able to measure this environment in both expected and unexpected ways. Cassini Plasma Spectrometer (CAPS) measures ions, electrons and photo-electrons and also measures the energy/charge of charged nanograins when present. When the plasma is sufficiently dense the Cassini Radio Plasma Wave Sensor (RPWS) and Magnetometer (MAG) data can be used to derive electron density and RPWS also detects dust impacts. Langmuir Probe (LP) measures the electron density and temperature via direct current measurement. The Magnetospheric Imaging Instrument (MIMI) measures energetic particles as well as energetic neutral atoms produced during charge exchange interactions in and near the plumes. The Ion Neutral Mass Spectrometer (INMS) measures ions and neutral molecules and the Cosmic Dust Analyser (CDA) measures down to micron sized dust. By consolidating data from these Cassini sensors we will present an assessment of the near Enceladus environment, discuss what is consistent and otherwise, and the implications for the plasma environment at Enceladus in the context of work to date as well as implications for future studies.

Friday, June 16 – 11:45

Cassini at Titan: What have we learned after more than a decade of observations?

Darci Snowden

* Central Washington University

Abstract

Before Cassini, our understanding of Titan's interaction with Saturn's magnetosphere was based on measurements from a single Voyager flyby. Over the past decade, data from over 100 close encounters has challenged that understanding. For example, Cassini discovered that the production of the massive molecules in Titan's atmosphere begins in the thermosphere, which is strongly altered by Titan's space environment. Cassini also revealed that Titan's impact on Saturn's magnetosphere is weaker, or at least much more subtle, than originally assumed. It is clear that Titan's environment is complex and variable. The persistent flapping of Saturn's magnetodisk causes periodic changes in the plasma and field near Titan. On several occasions, Cassini even found Titan outside of Saturn's magnetosphere in the solar wind. Superimposed on the short-term magnetospheric fluctuations are many-year seasonal and solar cycle changes that only a mission like Cassini could have revealed. In this talk, I will review what we have learned after more than a decade of observations and I will summarize some of the questions that remain.

Friday, June 16 – 12:05

Titan's ionospheric ions ¬through the solar cycle

O. Shebanits, E. Vigren, J.-E. Wahlund, M.K.G. Holmberg, M. Morooka, N.J.T. Edberg, K.E. Mandt, J.H. Waite Jr

* Swedish Institute of Space Physics

Abstract

We present a study of the effects of varying solar EUV flux on the ions in Titan's ionosphere, utilizing the 12 years of RPWS/LP measurements. The focus is on the positive ions and heavy negative charge carriers (molecular ions, aerosol and/or dust) below 1200 km altitude. The measured ion charge densities increase by factor 2 on the dayside and decrease by factor 4 on the nightside from solar minimum to maximum (contrary to the Chapman theory), hinting at photo-chemical process(es) eliminating long-lived ions proportionally to the EUV flux. During the maximum solar activity, the altitude of the positive ion charge density peaks decreases and the altitude of the negative ion/dust grain charge density peaks increases. Nightside charge densities are found to be higher in the Saturn's sunward magnetosphere compared to the magnetotail. Removing the SZA and EUV dependencies from the charge densities reveals seasonal variations, with 50% increase from summer to winter.

Friday, June 16 – 12:20

Observations of photoelectron energy peaks in Titan's ionosphere

Anne Wellbrock, Raquel Caro-Carretero, Yutian Cao, Andrew J. Coates, Geraint H. Jones

* Mullard Space Science Laboratory, University College London

Abstract

Cassini's CAPS Electron Spectrometer (ELS) has observed discrete energy peaks at 24.1 eV in the electron spectra in Titan's ionosphere. These electrons are believed to be photoelectrons generated due to the ionisation of N2 by the strong solar He II (30.4nm) line. They are generally observed in Titan's dayside ionosphere, because this is where neutral N2 particles can be ionised by solar radiation. Photoelectron peaks are also observed at large distances from Titan, where they are unlikely to have originated because of low neutral N2 densities. The most likely explanation for their existence at these locations is that they travelled along magnetic field lines to the observation sites from the dayside ionosphere, where they were created. Photoelectrons can therefore be used as tracers of magnetic field lines. In this paper we present recent results based on an automatic finite impulse response algorithm which detects photoelectron peaks in electron spectrometer data.

Friday, June 16 – 14:00

Plasma transport out of the Io torus: Open questions

Vytenis M. Vasyliunas

* Max-Planck Institut für Sonnensystemforschung

Abstract

The Io torus is the primary source of plasma for the magnetosphere of Jupiter, and a number of unanswered or only partially answered questions remain about processes by which the material supplied at a quasi-steady rate from the moon Io is transported outward and ultimately removed from the Jovian system, without removing the magnetic flux that is coupled to the plasma. The transport mechanism within the nearly corotating inner magnetosphere is universally assumed to be by diffusion resulting from an interchange instability, but its properties and in particular the geometry of outward and inward flowing flux tubes are described on the basis more of rough concepts (reflecting the most recent observations) than of established theory. The outward transport/outflow in the markedly subcorotating magnetotail and its continuation into the distant tail/wake is closely connected with processes which allow magnetic flux carried by the plasma to be detached so it can return to the inner magnetosphere. The so-called Vasyliunas cycle, devised specifically as the simplest representation of magnetic topology changes required to effect the flux return, raises fundamental questions about reconnection on closed magnetic field lines, as well as about a magnetotail dominated by interior stresses.

Friday, June 16 – 14:15

Io's plasma interaction with Jupiter's magnetosphere: Influence of global asymmetries in Io's atmosphere and volcanic plumes on the plasma environment

Aljona Blöcker, Joachim Saur, Lorenz Roth

* University of Cologne

Abstract

Io's atmosphere is supported by sublimation of SO2 surface frost and by direct volcanic outgassing of SO2. The atmospheric density has been investigated by various observations and methods revealing a dense atmospheric ring around the equator with pronounced longitudinal asymmetries. Local density enhancements at volcanically active regions might be present in addition. We apply a 3D MHD model to analyze the effects of longitudinal asymmetries in the global atmosphere as well as the role of volcanic plumes on the plasma interaction. We demonstrate that significant parts of the magnetic field perturbations, associated with the induction signals from a subsurface magma ocean by Khurana et al. (2011) can alternatively be explained by considering the longitudinal asymmetries in the atmosphere (not considering plumes). Including local volcanic plumes, we furthermore show that such local density enhancements influence the plasma interaction locally but do not significantly change the mass supply rate to the plasma torus.

Friday, June 16 – 14:30

Enhancement of Jovian magnetospheric plasma circulation due to mass supply change from the satellite Io

Fuminori Tsuchiya, Tomoki Kimura, Kazuo Yoshioka, Mizuki Yoneda, Ryoichi Koga, Masato Kagitani, Go Murakami, Chihiro Tao, Hiroaki Misawa, Atsushi Yamazaki, Ichiro Yoshikawa, Yasumasa Kasaba, and HISAKI science team

* Tohoku University

Abstract

The inner most Galilean satellite Io supplies a large amount of volcanic gas to the Jovian magnetosphere. Outward transport of the ionized gasses is responsible for forming a huge and rotation dominant magnetosphere. The plasma supply from the satellite has a key role to characterize this rotation dominant magnetosphere. From continuous data set of the Io plasma torus (IPT) obtained from an extreme ultraviolet spectroscope onboard the HISAKI satellite, significant variation of plasma population in the inner magnetosphere due to volcanic eruption on the satellite was found in 2015 and enhanced plasma supplies from inner to middle magnetosphere occurred from the middle of Feb. to Apr. Strong short-lived aurora brightenings which represented transient energy release in the outer part of the magnetosphere occurred frequently during this period. Several hours after the aurora brightening, sporadic enhancement of ion brightness in the IPT were identified and they lasted for a few tens hours. This indicates that the energy released transport inward in the time scale of several hours and causes to increase hot electron population in the inner magnetosphere. This is the first observational evidence to show that a plasma source strength in the inner magnetosphere controls a large scale circulation of mass and energy in a rotation dominant magnetosphere.

Friday, June 16 – 14:45

Behavior of hot electrons in the Io Plasma Torus during the transient brightenings confirmed by Hisaki/EXCEED observation

Reina Hikida, Kazuo Yoshioka, Go Murakami, Tomoki Kimura, Fuminori Tsuchiya, Ichiro Yoshikawa

* University of Tokyo

Abstract

EXCEED on Hisaki spacecraft has identified more than 50 pairs of brightenings of the Io Plasma Torus (IPT) and aurora. For each pair, auroral brightening was the first and the IPT brightening was lagged by about 10 hours. This unique behavior indicates the existence of the inward flow of hot electrons toward the IPT from the distant region (magnetically connected to the polar region). The inward flow might be "the additional energy transfer" in order to sustain the radiation from IPT. Applying the spectral diagnosis method to EUV spectra obtained by EXCEED, we conclude that some IPT brightenings were due to the increase in hot electron (>100 eV) density.

Friday, June 16 – 15:00

CPEM: An empirical probability model of cold plasma environment in Jovian inner magnetosphere

Yoshifumi Futaana, Xiao-Dong Wang, Elias Roussos, and JCAT/CPEM team

* Swedish Institute of Space Physics

Abstract

A new empirical, analytical model of cold plasma (100 eV – 10 keV) in the Jovian inner magnetosphere is constructed. Plasmas in this energy range impact surface charging of spacecraft. A notable feature of this new model is for predicting each plasma parameter for a specified probability (percentile). The new model was produced as follows. We start from a reference model for each plasma parameter, which was scaled to fit the data obtained from Galileo plasma spectrometer. The scaled model was then represented as a function of radial distance, magnetic local time, and magnetic latitude, presumably describing the mean states. This is called mean model. Then, the deviation of the observed values from the mean model were attribute to the variability in the environment, which was accounted for by the percentile at a given location. This is called as percentile model. The supported parameters are plasma density, ion temperature, ion bulk velocity vector, hot electron density and the temperature. The input parameters for this model are the spacecraft position (9 and 30 Rj) as well as the percentile. The model is intended to be used for the JUICE mission analysis.

Friday, June 16 – 15:15

Characterizing Io's Plasma Torus at Visible Wavelengths in the Hisaki Era

Carl Schmidt, Nick Schneider, Francois Leblanc, Candace Gray, Jeff Morgenthaler, Jake Turner, Cesare Grava

* LATMOS

Abstract

To complement Hisaki's UV observation of the plasma torus, we've assembled a comprehensive ground-based dataset at visible wavelengths from Apache Point Observatory. These data can help characterize the torus' radial and azimuthal structure via S+, S++, and O+ emissions, which are excited via thermal electron impacts. We derive the electron density and temperature from their line of sight emission ratios along the centrifugal equator. The mean density peaks at 3500 cm-3, with the dusk side being denser and more spatially confined than the dawn side. Dawn-side line ratios near Io's orbit suggest core electron temperatures are significantly colder (2 eV) than the surrounding regions. Recurrent traits in the brightness and location of torus emissions are discerned as a function Jovian longitude (λIII). Longitudinal modulation of S+ brightness differs from prior optical data, but is broadly consistent with concurrent Hisaki measurements. Measured positions of the "ribbon" feature match the known λIII behavior in prior data and exhibit a lesser wobbling motion than would the centrifugal limit along a given magnetic L shell as Jupiter rotates. The torus is displaced 0.125 RJ, on average, towards 07:00 local time by a 4 mV/m dawn-dusk electric field. Brightness shows no correlation with proximity to Jupiter, nor to Io phase, and exhibits no regular dawn-dusk asymmetry. These traits in the UV may then result from differences in plasma temperature, rather than density.

Poster Session 1

Tuesday, 13 June

#1

Statistical properties of Flux ropes at Titan: Cassini magnetometer observations

C. S. Arridge, S. V. Badman

* Lancaster University

Abstract

Flux ropes are a common feature in magnetised plasma regimes across the Solar system from the solar wind and the corona, to the ionospheres of Venus, Mars, Earth and Titan. 73 flux ropes are detected at Titan using the Cassini magnetometer during flybys between Jan 2005 and Jan 2016. We find that flux ropes are more commonly found during flybys that occur near noon in Saturn's magnetosphere. A force-free flux rope model is utilised to estimate the range of radii and axial magnetic field strengths at the centre of Titan's flux ropes. We find that the flux ropes have radii that range from 50 – 500 km and maximum axial field values of 1 – 10 nT, however a small number of flux ropes have a considerably larger maximum axial field. We comment on the Saturn local time differences in flux rope morphology and Titan's plasma environment.

#2

Ion Precipitation into Titan's Atmosphere over Short and Long Timescales

Darci Snowden, Skylier Jones, Alex Higgins

* Central Washington University

Abstract

The precipitation of magnetospheric ions into Titan's atmosphere can affect the dynamics and structure of Titan's upper atmosphere on short time scales and the composition and chemistry on longer time scales. Previous work has assumed that the oxygen flux into Titan's atmosphere was similar to the flux estimated from Voyager 1 data. However, the density of water group ions measured by Voyager 1 is higher than the density measured by Cassini near Titan's orbit. We will present an updated description of the flux of water group ions into Titan's atmosphere. First, we use CAPS-IMS data to determine the range of magnetospheric W+ fluxes near Titan's orbit. The precipitation of water group ions into Titan's atmosphere is affected by the configuration of Titan's induced magnetosphere. Therefore, we use a 3D ion precipitation model to calculate the number and energy flux through Titan's exobase for the range of magnetospheric fluxes observed by CAPS-IMS.

#3

Titan's Topside Ionospheric Composition: Cassini Plasma Spectrometer Ion Mass Spectrometer Measurements

Edward C. Sittler Jr., Richard Hartle, Ashraf Ali, John Cooper, Alexander Lipatov, David Simpson, Menelaos Sarantos, Marcus Shappirio, Dennis Chornay, Todd Smith

* NASA Goddard Space Flight Center

Abstract

We present ion composition measurements of Titan's topside ionosphere using both T9 and T15 Cassini Plasma Spectrometer (CAPS) Ion Mass Spectrometer (IMS) measurements. The IMS is able to make measurements of Titan's ionosphere due to ionospheric outflows as originally reported for the T9 flyby. This allows one to take advantage of the unique capabilities of the CAPS IMS which measures both the mass-per-charge (M/Q) of the ions and the fragments of the ions produced inside the sensor such as carbon, nitrogen and oxygen fragments. The CAPS IMS uses a time-of-flight (TOF) technique which accelerates ions up to 14.6 kV, so they can pass through ultra-thin carbon foils. We preliminarily find, by using IMS measurements of T9 and T15 ionospheric outflows, evidence for methane group ions, nitrogen ions, water group ions and evidence for heavier hydrocarbons such as C2H5+ and HCNH+ within Titan's topside ionosphere.

#4

Electron population in Titan's ionosphere: interpretation of Cassini dataset and open questions

E. Vigren, M. Galand, J.-E. Wahlund, J. Cui, O. Shebanits, N.J.T. Edberg, A. Wellbrock, A. J. Coates, P. Lavvas, V. Vuitton

* Swedish Institute for Space Physics

Abstract

We review a series of studies focusing on the electron balance and ionization sources in Titan's upper atmosphere. We highlight some discrepancies between model results and observations. For instance, solar energy deposition models applied to the dayside ionosphere, and driven by INMS/CSN and TIMED/SEE measurements, predict systematically higher electron number densities and higher photoelectron fluxes than observed by the RPWS/LP and CAPS/ELS, respectively. We discuss possible causes for these discrepancies.

#5

A case study of the variability of Titan's ionosphere: T118 and T119

Niklas Edberg, Erik Vigren, Jan-Erik Wahlund

* Swedish Institute of Space Physics

Abstract

We present measurements from the Cassini Radio and Plasma Wave Science/Langmuir probe (RPWS/LP) instrument of the electron density in the ionosphere of Titan during the T118 and T119 flybys. Even though the flyby geometry is similar, the electron density varies significantly from one flyby to the next. In the altitude range 1150 -1250 km there is no significant difference in density between the two flybys, while both above and below (in the ranges 980-1150 km and 1250-1500 km) there is as much as a factor 5 difference in electron density. The differences are measured to be present both during the inbound and the outbound leg of the Cassini flyby. Comparing to previous flybys at the same location in SZA and altitude it seems as if the plasma is depleted during T118, while the electron density is around average during T119.

#6

Ions and dust in Titan's ionosphere: A multi-instrument case study

O. Shebanits, J.-E. Wahlund, N. J. T. Edberg, F. J. Crary, A. Wellbrock, D. J. Andrews, E. Vigren, R. T. Desai, A. J. Coates, K. E. Mandt, and J. H. Waite Jr

* Swedish Institute of Space Physics

Abstract

We present ion charge densities and the first empirical estimate of the negative ions/dust grain charge, derived using combined independent in situ plasma (RPWS/LP) and particle (CAPS/ELS, CAPS/IBS and INMS) measurements of Titan's ionosphere during flybys T16, T29, T40, and T56. The results show an ion-ion (dusty) plasma below 1100 km altitude (electron depletion $>$90%), with charge densities factor $\geq$2 larger than the ionization density peaks from the primary ionization sources. We suggest that ion-ion (dusty) plasma is also present in the dayside ionosphere below 900 km ($>$50% electron depletion at 1000 km altitude). The average charge of the dust grains $\geq$ 1000 amu is estimated to be between -2.5 and -1.5 elementary charges, increasing toward lower altitudes.

#7

The aurorae of Uranus past equinox

L. Lamy, R. Prangé, K. C. Hansen, C. Tao, S. W. H. Cowley, T. Stallard, H. Melin, N. Achilleos, P. Guio, S. V. Badman, T. Kim, N. Pogorelov

* LESIA - Observatoire de Paris

Abstract

The aurorae of Uranus were recently detected in the far ultraviolet with the Hubble Space Telescope (HST) providing a new, so far unique, means to remotely study the asymmetric Uranian magnetosphere from Earth. We analyze here two new HST Uranus campaigns executed in Sept. 2012 and Nov. 2014 with different temporal coverage and under variable solar wind conditions numerically predicted by three different MHD codes. Overall, HST images taken with the Space Telescope Imaging Spectrograph reveal auroral emissions in three pairs of successive images (one pair acquired in 2012 and two in 2014), hence six additional auroral detections in total, including the most intense Uranian aurorae ever seen with HST. The detected emissions occur close the expected arrival of interplanetary shocks. They appear as extended spots at southern latitudes, rotating with the planet. They radiate 5-24 kR and 1.3-8.8 GW of ultraviolet emission from H2, last for tens of minutes and vary on timescales down to a few seconds. Fitting the 2014 observations with model auroral ovals constrains the longitude of the southern (northern) magnetic pole to 104 ± 26○ (284±26○) in the Uranian Longitude System. We suggest that the Uranian near-equinoctial aurorae are pulsed cusp emissions possibly triggered by large-scale magnetospheric compressions.

#8

HST remote observations of Saturn's aurorae during the Cassini Grand Finale

Laurent Lamy, Sarah Badman, Frank Crary Renee Prangé, John Clarke, Philippe Zarka, Baptiste Cecconi, Bill Kurth, Don Mitchell, Wayne Pryor, Ulyana Dyudina, Emma Bunce, Michele Dougherty, Katerina Radioti, Jonathan Nichols, Marcia Burton

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Abstract

Observations of Saturn's UV aurorae with the Hubble Space Telescope (HST) started in mid-2016 to provide a ground-based support to the Cassini end of mission. HST remote observations of the northern aurorae were primarily scheduled when Cassini samples in situ the auroral regions during F-ring and proximal orbits, to assess fundamental plasma physics processes including acceleration, wave-particle interaction and energy/momentum transfer. Several HST orbits were also coordinated with Cassini remote imaging of the southern aurorae before F-ring orbits to achieve a simultaneous view of both hemispheres and investigate magnetic (non-)conjugacy.

#9

Magnetohydrodynamics (MHD) simulations of the interaction of the solar wind with Saturn and Uranus

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Abstract

We present 3D magnetohydrodynamics (MHD) simulations (on a spherical grid) of the interaction of the solar wind with a fast rotating magnetized planet, with arbitrary orientation of magnetic and spin axis. The large-scale flow in fast-rotating planets' magnetosphere – which is the case of the four outermost planets – results from both the solar wind interaction and the planetary rotation and is described here for different orientations of the interplanetary magnetic field. We present in particular the effects of the fast rotation of the planet on the configuration of the planet-connected magnetic field lines and on the flow dynamics. We run the MPI-AMRVAC code, adapted for this kind of interaction, to the magnetosphere of Saturn and possibly to the case of Uranus.

#10

The Variability of the Saturn-Titan Interaction as Observed with Energetic Neutral Atoms (ENAs) from Cassini MIMI-INCA

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Abstract

At the end of the Cassini mission it will have performed 127 targeted Titan flybys and a multitude of non-targeted, higher altitude flybys. Every flyby the Cassini INCA ENA camera [Krimigis et al., 2004] observes the moon-magnetosphere interaction using charge exchange of the magnetospheric ions with the dense neutral atmosphere of Titan. The multitude of Titan flybys have given several different vantage points for ENA imaging of the moon-magnetosphere interaction revealing an extended atmosphere [Brandt et al. 2012], intriguing ENA morphology related to the magnetic field [Wulms et al. 2010], and several other temporal features [e.g. Mitchell et al, 2005]. Due to the nature of the input plasma and its pitch angle distribution and the shadowing of ENAs from Titan's atmosphere it is crucial to utilize the multitude of vantage points to really understand this interaction. In this paper we present a compilation of the INCA ENA observations at Titan showing the flybys and specific times where good, clean ENA observations are available as well as pointing out specific features in the ENA observations such as bursts of heavy ion ENA emissions and unique temporal features. This list of observation times and features can be used in conjunction with the upstream conditions and field configurations from the work of Simon et al. 2010, 2013, Rymer et al. 2009, and Garnier et al. 2010 to further refine the models of the Titan moon-magnetosphere interaction.

#11

Energetic plasma environment at Titan's orbit

Leonardo Regoli, Elias Roussos, Janet Luhmann, Kostas Dialynas, Xianzhe Jia, Abigail Azari, Norbert Krupp, Geraint Jones, Andrew Coates

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Abstract

Titan, Saturn's largest moon, is located in the outer region of the magnetosphere, very close to the average magnetopause stand-off distance. Due to this specific location, Titan is subject to a highly variable magnetospheric environment that is governed by different factors such as the location of the magnetopause (when located close to the noon sector) and the flapping motion of the magnetospheric current sheet.

In this work, the energetic environment at the moon's orbital distance is analyzed using data collected over more than 10 years during close flybys and orbital crossings (far from the moon) by the MIMI/LEMMS and MIMI/CHEMS instruments on board Cassini.

The data is organized by different parameters including location of the moon with respect to the current sheet and Saturn local time (SLT). In addition, a modified Kappa distribution function is fitted to the data with the aim of deriving an empirical model of the upstream fluxes that the moon can encounter at different SLT sectors.

The results show an environment that is even more variable than that observed using other data sets such as low energy ions and electrons (CAPS/IMS and CAPS/ELS) as well as magnetic field data (MAG). Asymmetries are found on the data that seem to indicate a dependence on large magnetospheric flow patterns and have an apparent correlation with observed variations in the moon's ionospheric densities.

#12

Low Frequency Extensions of the Saturn Kilometric Radiation as a proxy for magnetospheric dynamics

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Abstract

Saturn Kilometric Radiation (SKR) is a radio emission formed via the cyclotron maser instability on field aligned currents near the auroral regions of Saturn. The SKR has been found to respond to both internal and external driving, and to be linked to both solar wind compressions and magnetotail reconnection events. The radio emission is remotely sensed quasi-continuously and therefore offers the potential to be used as a proxy for magnetospheric activity when the spacecraft is not in an ideal viewing region for observing in-situ signatures of reconnection. In this work, we use data taken by the Cassini magnetometer and radio and plasma wave sensor while Cassini was executing its deepest tail orbits in 2006. We characterise the behaviour of the SKR over this period and develop an automatic method for finding low frequency extensions (LFE), where the SKR emission extends down to lower frequencies below the main band. LFEs have been shown to occur in response to reconnection at Saturn (Jackman et al, 2009) and also in response to solar wind dynamics (e.g. Bunce et al, 2005, Badman et al, 2008) We present a statistical analysis of our LFE catalogue, discussing correlation with known tail reconnection events and upstream solar wind conditions. We examine the properties of LFEs in the context of spacecraft viewing constraints, and discuss their relationship to the planetary periodicities.

#13

North-south asymmetry of Saturn's auroral radio emissions: The seasonal variation of their fluxes in half of Kronian year

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Abstract

The observations by Cassini from 2004 to 2017 is revealing its strange seasonal variation seen in the magnetic field and upper atmosphere. In this study, we extend our SKR flux variation study from southern summer season [Kimura et al. 2013] to cover the half Kronian year, from southern summer to northern summer. The simple extension of the analysis method used in our previous study was not adequate because of the bias in the Cassini orbit. We only used the data for 2004-2010 when Cassini was at the dawn side (2-10h LT). However, because of Cassini's apokrone after 2007 was gradually shifted from dawn to dusk. For this study to cover 2004-2016, we used the data in all local time. In order to avoid the dawn-dusk asymmetry effect, we selected the data when Cassini was in the latitude within +-5deg and both northern and southern SKR are observed simultaneously. The flux ratio between them can be used to evaluate the seasonal effect. In this result, the intensity of LH component in 2004-2009 (south, summer) was +10 dB stronger than RH (north, winter), which is consistent with the result in Kimura et al. (2013). In 2010-2012, the both SKR intensities got close to each other. After 2013, RH (north, summer) was slightly stronger by a few dB than LH (south, winter). The flux ratio was more than 10 in southern summer but only 2.5 5 in northern summer, in the analyzed term, even in 2014-2015.

#14

Seasonal variation of energetic C+ and CO+ abundances in Saturn's magnetosphere related to ring illumination

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Abstract

In mid-2014 the Cassini/CHEMS instrument observed a rather dramatic increase in the relative abundances of both C+ and CO+ (factors of 2 to 4). The enhancements then decreased during 2015 and 2016, with CO+ decreasing more quickly. C+ and CO+ (actually mass 28 molecular ions that could also include N2+) are trace components of the energetic (50-220 keV) ion population in Saturn's magnetosphere, which is dominated by water group ions W+ (O+, OH+, and H2O+ and H30+), H+, and H2+.

We suggest that the C+ and CO+ enhancements are associated with CO2, probably from Enceladus, building up on the cold rings near equinox, but then being released from the north side of the rings as they warmed above 80K in 2012 or so (Flandes et al, 2010) due to increasing solar illumination after the 2009 equinox. Hodyss et al (2008) found preferential sublimation of CO2 from a CO2:H2O ice mixture when it was warmed above 80K. Transport, dissociation, ionization, and acceleration of the C+ and CO+ in the magnetosphere would then produce the observed energetic ions, with the enhancements subsiding as the CO2 was depleted.

We will report the relevant abundance ratios from 2004 through the F ring orbits in 2017 to test this hypothesis as well as our latest attempts to distinguish CO+ from N2+ in the CHEMS data.

Flandes, A. et al, Planet. Space Sci, 58, 1758-1765, 2010. Hodyss, R. et al, Icarus, 194, 836-842, 2008.

#15

Detecting dust hits around Saturn in CAPS / ELS Data from Cassini

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Abstract

Hypervelocity dust grains have been noticed in CAPS / ELS data around several Enceladus flybys (1). Vaporized dust plasma shows up as simultaneous bursts in multiple look directions within the ELS detector. These bursts are very short in duration, and therefore are detected only in the few energy channels over which ELS happens to be sweeping at the time of the dust hit. A comprehensive search for similar events was made throughout the ELS dataset covering the Saturn tour from 2004 to 2012. Over 500 hundred candidate dust events were found, many of them not associated with Enceladus. Presented here is the algorithm for finding the dust hits in ELS data, as well as the spatial distribution of all dust events found.

#16

Planetary period oscillations in Saturn's magnetosphere: The crossing of the periods and surprises on the F-ring orbits.

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Abstract

We investigate planetary period oscillations (PPOs) in Saturn's magnetosphere using Cassini magnetic field and SKR data over the interval from late 2012 to May 2017. This interval includes the F-ring and pre F-ring orbits, which have a cadence of 11 days and below. Until mid-2013 the Southern PPO period remained longer than the Northern. Then in mid-2013 the two periods coalesced at 10.66 h and remained coalesced until mid-2014. During coalescence the two systems were locked near magnetic antiphase with SKR modulations in phase, a condition in which the effects of the generating rotating twin vortex flows in the two ionospheres reinforce each other via hemisphere-to-hemisphere coupling. The magnetic-SKR relative phasing indicates the dominance of postdawn SKR sources in both hemispheres. In mid-2014 the two periods separated again, the northern increasing to 10.78 h by early 2017, similar to the southern period during southern summer, while the southern period remained fixed near 10.70 h, well above the northern period during southern summer. This behavior resulted in the first enduring reversal of the two periods during the Cassini era. We further report on new results from the F-ring orbits. During these polar orbits we determine the periods and amplitudes of the two oscillations separately in the northern and the southern open field regions. Despite this we show coherent modulations of the periods and amplitudes of the two oscillations over their beat cycle.

#17

Ion acceleration above Saturn's polar ionosphere as measured in Energetic Neutral Atom emission: new results from the Cassini high latitude F-Ring orbits.

Donald G. Mitchell

* JHU-APL

Abstract

As the Cassini-Huygens Mission to Saturn and Titan draws near its end, the penultimate set of orbits are short period, high inclination orbits crossing the equator just outside the F-Ring on the dayside. As the spacecraft approaches periapsis over the north pole, and exits from periapsis over the south, the spacecraft attitude often allows for energetic neutral atom (ENA) imaging of the polar regions at distances closer than any previous opportunities in the mission. Furthermore, the final set of orbits, with periapsis inside the D-Ring, will afford such opportunities from even closer. For ENA imaging, this proximity allows the Magnetospheric Imaging Instrument (MIMI) Ion and Neutral Camera (INCA) to begin to resolve the spatial distribution of this emission, thought to result from wave-particle acceleration perpendicular to the local magnetic field of ionospheric ions in auroral current driven processes. We find that the emission peaks at an altitude of about 0.1 Rs, though it extends upward from that altitude. The emission profile is strongly influenced by the neutral exospheric density profile, and pitch angle effects make this emission visible only from near perpendicular lines of sight, so while the lower bound can be seen in these images, any upper bound has not yet been determined as the accelerated ions form conics with smaller opening angles as they stream up onto weaker fields.

#18

Advances on the magnetospheric dynamics of Saturn revealed from UVIS/Cassini auroral observations during the Grand finale phase of the mission

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Abstract

Auroral observations are a powerful tool to study the magnetospheric processes as they provide a 'global picture' of the magnetosphere at once. Here we present UVIS/Cassini auroral observations during the Grand Finale phase of the mission. As the spacecraft approaches closely Saturn's poles it offers an unprecedented view of the dayside and nightside auroral regions. Auroral observations which have been recently analysed from the beginning of the F-ring orbits reveal dusk/midnight arcs with a large latitudinal extent, suggesting that they are related to a source region extending from the outer to middle/inner magnetosphere. Their presence is shown to initiate dawn auroral enhancements and poleward expansions which display irregular shaped structures. Following the terrestrial example, we suggest that at Saturn the dusk/midnight arcs (possible signatures of planetward propagating plasma flows) might have caused a magnetospheric reconfiguration event, which is manifested as enhancement and poleward expansion of the dawn aurora. While the aforementioned discussion provides only the results based on the early Cassini F-ring orbits, we will also present auroral observations from the upcoming orbits with conjugate in-situ measurements. In particular, we will discuss the advances on magnetospheric dynamics at Saturn through the eyes of UVIS, during the final months of the mission.

#19

Variability in high latitude magnetic field observations at Saturn

Ewen Davies, Adam Masters, Michele Dougherty, Andrew Coates, K.C. Hansen, Nick Sergis

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Abstract

Swept forward field is the term given to configurations of magnetic field wherein the field lines deviate from the meridional planes of a planet in the direction of its rotation. Instances of this configuration are investigated on both the dusk side of Saturn, using data from the Cassini magnetometer and particle instruments. In the dusk case, nine orbits are surveyed; all show evidence of swept forward field. Typical sweep angle is found to be 23°. Evidence is found for transient events that lead to temporary dramatic increases in sweep-forward angle. The Michigan Solar Wind Model (mSWiM) is employed to investigate temporal correlation between the arrival of solar wind shocks at Saturn with these transient events, with two shown to include instances corresponding with solar wind shock arrivals. Results of a broader survey of high-latitude magnetic field measurements on the dayside (dawn and dusk) will also be reported.

#20

Survey of plasma composition in Saturn's magnetosphere

Marianna Felici, Christopher Arridge, Andrew Coates, Rob Wilson, Michelle Thomsen, Dan Reisenfeld

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Abstract

The Cassini mission has orbited Saturn since 2004, and in 2006 it started exploring the deep magnetotail, reaching distances of about 68 RS (where RS is the equatorial radius of Saturn). Since Cassini covered a broad area of Saturn's magnetosphere, this raises the question of what is the typical and atypical plasma composition in different regions of Saturn's environment. We present a survey of the bulk plasma composition using data from the Time of Flight instrument on CAPS/IMS on Cassini, from 2004 to 2013. This is the most comprehensive study ever made of relative abundances of thermal plasma at Saturn, maximizing the use of Cassini's orbital coverage in Saturn's magnetosphere and, therefore, the sensitivity to seasonal or natural variability of the system.

We studied the ratio between ions with mass per charge equal to two (either H2+ or He++) and ionized hydrogen ([(m/q=2)]/[H+]), and ionized ions produced from water (indicated with W+) and ionized hydrogen ([W+]/[H+]). We present the data as a function of position in the magnetosphere, radial distance and local time, and distance from the planet and longitude in respect to the moons Enceladus, Dione, Rhea, and Titan.

We found that the plasma composition in Saturn's magnetosphere presents significant local time asymmetries and variability.

#21

Energy-banded ions in Saturn's inner magnetosphere: Consequence of field line resonance?

M. F. Thomsen, S. V. Badman, C. M. Jackman, X. Jia, M. G. Kivelson, and W. S. Kurth

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Abstract

Using data from the Cassini/CAPS ion mass spectrometer, we report the first observation of energy-banded ions at Saturn. Observed near midnight at relatively high magnetic latitudes, the banded ions are dominantly H+, and they occupy the range of energies typically associated with the thermal pick-up distribution in the inner magnetosphere, but their energies decline monotonically with increasing radial distance (or time or decreasing latitude). The band energies, including their pitch-angle dependence, are consistent with a bounce-resonant interaction between thermal H+ ions and the standing wave structure of a field line resonance.

#22

The Fried Egg Velocity Distribution

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Abstract

Ion velocity distributions in the magnetospheres of Jupiter and Saturn can be considered a blend of two components: an isotropic core distribution of relatively low energy and high density, and a highly anisotropic distribution of relatively high energy and low density. Modeling this velocity distribution assists calculating the equilibrium distribution of the plasma along realistic magnetic field lines under the influence of centrifugal and electrostatic forces. Such extrapolation is essential for connecting in situ plasma measurements to remotely observable torus emissions as well as comparing high latitude and equatorial measurements. We have devised a model velocity distribution for this purpose, consisting of a Maxwellian function of parallel velocity times a generalized Lorentzian or kappa function of perpendicular velocity. We discuss the properties of this hybrid velocity distribution function, and illustrate its application in the analysis of plasma data at Jupiter and Saturn.

#23
Seasonal and solar cycle modulations of Saturn's inner plasma disk

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Abstract

We present 12 years of plasma measurements from the Cassini mission, focusing on the outer ring region from 2.5 to 12 Saturn radii (1 Rs = 60,268 km). A new analysis method is used to obtain ion density, n_i, from Langmuir probe (LP) measurements. The LP n_i is compared to, and shows a good agreement with, the electron density, n_e, derived from upper hybrid resonance frequency measurements in the region outside of 4.5 Rs. Within this region n_e is up to a factor 2 larger than n_i, which is suspected to be due to the interfering effects of dust and cluster ions that are present within 4.5 Rs. We study the seasonal and solar cycle dependencies of the equatorial plasma density and show that, unexpectedly, the plasma modulation outside of 3.7 Rs shows a stronger correlation to the solar cycle than the seasonal variation. However, the theoretical estimate, around 10 cc at 3.5 Rs, of the plasma modulation due to the varying EUV flux cannot explain the measured plasma variation, up to around 40 cc at 3.7 Rs. This indicates that an additional process, possibly a EUV flux dependency in the hot electron temperature, and not only the photoionisation directly, is increasing the EUV dependency of the plasma modulation. The measurement results from the 2017 orbits will be the key in deriving the importance of seasonal versus solar cycle dependencies, since the insolation angle then will be large (corresponding to large n_i) and the EUV flux low (corresponding to low n_i).

#24
Radial and local time structure of the Saturnian Ring Current

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Abstract

We present the radial and local time distribution of the full particle pressure and plasma beta in Saturn's magnetosphere for distances 5-16 Rs. The azimuthal current density and its components (inertial, P-gradient, and anisotropy) are computed as a function of radial distance and local time and presented as equatorial maps. Our results show that a) the particle pressure is controlled by thermal plasma inside of 8 Rs and by hot ions beyond 12 Rs, with higher pressures measured at the dusk and night sectors, b) plasma beta increases with radial distance and remains >1 beyond 8–10 Rs for all local times, c) the ring current is asymmetric in local time with a maximum of 115 pA/m^2 between 7 and 13 Rs, and (d) the ring current is inertial everywhere inside of 7 Rs, mixed in nature between 7 and 11 Rs and pressure gradient driven beyond 11 Rs. At local dawn the current is strongly pressure gradient driven, consistent with fast return flow of hot magnetospheric plasma.

#25

Plasma transport and magnetic flux circulation in Saturn's Magnetosphere.

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Abstract

Radial transport of plasma is an important dynamical process in Saturn's internally driven internally driven magnetosphere. It is suggested that the centrifugally driven interchange instability, due to Saturn's rapid rotation, is the major mechanism for radial transport processes. Stability is determined by radial gradients in flux tube content and flux tube entropy. Here, we will use both empirical and numerical models to estimate the flux tube content and entropy radial profile, which can provide important insight into magnetospheric dynamic properties. Observations of specific entropy suggest that there is non-adiabatic heating of plasma in inner magnetosphere. Observations using CAPS data and numerical modeling demonstrate that specific entropy indeed radially increases. However, the value of specific entropy is well organized in inner magnetosphere (i.e. L<10), and becomes widely scattered in middle magnetosphere, suggesting that the dynamics of inner and middle magnetosphere are different. We will discuss the connection between radial flows and the abnormal heating or cooling events.

#26

Momentum and Angular Momentum Exchange between Solar Wind, Magnetosphere and High Latitude Ionosphere at Saturn

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Abstract

The three-regime (Vasyliunas-Dungey-core polar cap) model of the Saturn magnetosphere described by Southwood and Chané (2016) is analysed further in light of data from Cassini spacecraft magnetometer from high latitude orbits and the MPI-AMRVAC simulation of an rotationally dominated aligned rotator magnetosphere. Local time dependence of magnetic stress is compared with the expectations of a regular high latitude background Dungey circulation, as suggested by Cowley et al. (2004). It is proposed that there is evidence in the Cassini magnetomer data for such a solar wind related plasma circulation at high latitudes. There are both local time dependent and rotationally dependent (10.7 hr oscillations) signatures in the high latitude magnetic field components measured by Cassini. It is pointed out that the aligned rotator simulation contains regular rotational magnetic signatures in all regimes including at highest latitudes in the polar cap. The local time dependent and rotational signatures are attributed as the effect of momentum and angular momentum exchange respectively. The preference for angular wave number m = 1 is explained and it is pointed out that, despite the presence of a resulting magnetic signal rotating at near 10.7 hrs period, the m = 1 MHD wave response does not imply strict corotation is enforced in the magnetosphere.

#27

Composition and density of F-ring neutrals and ions from INMS measurements

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Abstract

During Cassini's passes through the Janus gap in the F-ring, the Ion and Neutral Mass Spectrometer (INMS) observed ions and neutrals within 3,000 km of the equatorial plane. The neutrals are symmetric about the plane, but the ions differ in both density and composition between the north and south. The neutrals are measured using the Closed Source Neutral (CSN) mode, and the high velocity causes most molecules to dissociate. Chemical reactions between the dissociation products on the surface of the INMS antechamber then create the volatiles that INMS measures, finding hydrogen- and carbon-bearing volatiles, with oxygen also likely. The only ions that INMS observes are the water-group ions, which are cold, below 5 eV. The O2+ observed by INMS in 2004 during Cassin's pass over the A ring are outside the INMS energy range for the F-ring observations. The expected H2+ is not observed.

#28

Refurbishing Voyager/PRA data

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Abstract

Voyager/PRA (Planetary Radio Astronomy) data from digitized tapes archived at CNES have been reprocessed and recalibrated. The data covers the Jupiter and Saturn flybys of both Voyager probes. We have also reconstructed goniopolarimetric datasets (flux and polarization) at full resolution. These datasets are currently not available to the scientific community, but they are of primary interest for the analysis of the Cassini data at Saturn, and the Juno data at Jupiter, as well as for the preparation of the JUICE mission. We present the first results derived from the re-analysis of this dataset.

#29

Dynamics of Charged Particles Trapped in a Gas Giant Magnetodisc

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Abstract

The Earth's internal magnetic field is to a good approximation dipolar, and charged particles from the magnetosphere, depending on their kinetic energy, pitch angle and distance can remain trapped in this field. The motion of such trapped particles is characterised by their time scales –cyclotron (gyration), bounce and drift periods– and the position of the mirror point. High-energy electron and proton populations in the two radiation (van Allen) belts are such examples.

At the gas giants, Jupiter and Saturn, the total magnetic field deviates from a dipolar configuration due to internal sources of plasma provided by the moons Io and Enceladus respectively. In addition, the rapid rotation of these planets (period of order 10h) plays a role in the development of a disk-like field structure near the equator where centrifugal force is dominant - a configuration referred to as a magnetodisc.

We present results of numerical simulations of charged particle motion in such a magnetodisc field structure using particle tracing and the UCL Magnetodisc Model, and we use these simulations to characterise the time scales and mirror point, and quantify the differences between particle motion in magnetodisc and dipole fields.

#30

On the Elliptical Polarisation in Jupiter and Saturn Radio Emissions

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Abstract

Cyclotron maser (CMI) radiation at the origin of planetary low frequency radio emissions is by nature highly polarized. A significant part of the information about the particular CMI scenario in each planetary environment is contained, in principle, in polarisation properties. But subsequent propagation of the radiation to the observer often circularizes the initially linearly polarized emission. There are two particular cases in which a well-defined elliptical polarisation, - and likely the original one at the source -, can be observed. Namely: in the case of Jupiter decametric emission (DAM), as known for a long time, and in the case of Saturn kilometric radiation (SKR), when specific observing conditions are met. Here we discuss some recent observing facts, mainly obtained by using new technical and methodological achievements (e.g. multiple monopoles and correlation receiver aboard Cassini spacecraft, or large antenna arrays (LWA1, NDA) fed to high performance spectral correlators on the ground).

#31

Solar wind interaction, structure, and dynamics of the outer planet magnetospheres: A report on the ongoing activities of two ISSI teams

Marissa F. Vogt, Caitriona M. Jackman, Adam Masters, Chris P. Paranicas, Sarah V. Badman, Bertrand Bonfond, Emmanuel Chané, George Clark, Peter A. Delamere, William R. Dunn, Robert W. Ebert, Hiroshi Hasegawa, Suzanne M. Imber, Krishan K. Khurana, Elena A. Kronberg, William S. Kurth, Philippe Louarn, Jonathan D. Nichols, Aikaterini Radioti, Joe Reed, Elias Roussos, Andy W. Smith, Chihiro Tao, and Michelle F. Thomsen

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Abstract

In 2015 two teams of scientists were selected by the International Space Science Institute (ISSI) in Bern with similar goals of understanding the nature of the solar wind interaction with the magnetospheres of Jupiter and Saturn and the resulting structure and dynamics of the magnetospheric boundary regions. The team "How does the Solar Wind Influence the Giant Planet Magnetospheres?" is led by Marissa Vogt and Adam Masters and the team "Structure and Dynamics of Jupiter's Magnetosphere and Boundary Regions" is led by Caitriona Jackman and Chris Paranicas. Because these two teams share several overlapping scientific goals the teams decided to combine activities and hold a joint first meeting, which occurred in April 2016. The second team meeting will also be a joint meeting of the two teams and will be held in September 2017. Some of the outstanding research questions that the teams have been addressing include: "How do processes like magnetic reconnection and the viscous interaction at the Jovian and Saturnian magnetopauses compare to the same processes at Earth's magnetopause?" and "Is there evidence that the solar wind drives tail reconnection at Jupiter and Saturn? If so, what process (dayside reconnection, solar wind compression) is responsible?" Here we report on some of the initial team activities, which include data analysis, modeling, and theory. Additionally, we will take this opportunity to solicit input from the wider MOP community before the second team meeting.

#32

The prevalence of negative ions in Saturn's inner magnetosphere

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Abstract

Negative ions have been detected at several localized regions in the Saturnian system, including the plume of Enceladus and the upper atmosphere of Titan. We present the results of an analysis of Cassini CAPS-electron spectrometer (ELS) data to ascertain the distribution of negative ions in the planet's inner magnetosphere; a task naturally complicated by the strong foreground signal from electrons, which ELS was designed to detect. We comment on the implications of our results for our understanding of the neutral gas and ice grain sources in Saturn's E-ring.

#33

The electrostatic plasma environment of Hyperion

Andrew R. Poppe, Tom A. Nordheim, Michael I. Zimmerman, and Shahab Fatemi

* Space Sciences Laboratory, UC Berkeley

Abstract

Hyperion is a small, irregular outer moon of Saturn, orbiting at approximately 25 saturnian radii. This orbit exposes Hyperion to Saturn's outer magnetosphere and occasionally the magnetosheath and solar wind. During Cassini's only targeted fly-by of Hyperion on September 26, 2005, the Cassini Plasma Spectrometer observed a burst of electrons at 200 eV originating from the direction of Hyperion along the magnetic field line (Nordheim et al., 2014). Analysis of the CAPS data suggested that these electrons originated from the surface of Hyperion and were subsequently accelerated through a 200 V potential. We use a 2d electrostatic particle model to model the electrostatic surface charging and plasma wake environment of Hyperion during the 2005-09-26 observation as well as at other representative plasma environments encountered by Hyperion. Our results reproduce the presence of an electron beam originating from both photoelectrons and secondary electrons from the surface of Hyperion, bound to the magnetic field line, at approximately 200-400 V, consistent with the Cassini CAPS observations. We discuss the details of the hyperionian plasma interaction during this observation and during other typical plasma environments encountered by Hyperion. We explore the possibility that non-monotonic electrostatic potentials may be present at Hyperion, a phenomena which has only been previously observed at Earth's Moon.

#34

A Comprehensive Survey of Low-Frequency Plasma Waves in the Saturnian Magnetosphere

Zachary Meeks, Sven Simon, Frank Crary

* Georgia Institute of Technology

Abstract

Based on all available Cassini magnetic field data sets collected between 2004 and 2017, we construct a three-dimensional map of low-frequency plasma waves in the Saturnian magnetosphere between the orbits of Enceladus and Titan. First, we survey the data for ion cyclotron waves (ICWs), which can be applied to constrain the local ion production rate, as well as the mass of the newly-generated ions. We find that the occurrence rate of ion cyclotron waves decreases according to a Fermi-Dirac-like profile in radial direction, with only few waves observed beyond the orbit of Rhea. In north-south direction, the ICW amplitude decreases non-linearly with no waves occurring farther than two Saturn radii from the equatorial plane. The ICWs are generated in a narrow band (extension 0.3 Saturn radii) around the planet's equatorial plane and then propagate away from the magnetic equator in both hemispheres. We derive an analytical expression for the three-dimensional shape of the region populated by ICWs. We also analyze the distribution of mirror mode waves in Saturn's equatorial magnetosphere. We find that this wave mode occurs independent of Local Time. In radial direction we identify a transition region between L=5.5 and L=6.5 where a drastic drop of ion cyclotron wave occurrence is juxtaposed with the emergence of the mirror mode wave. On average, the dilute atmospheres around Dione and Rhea have no statistically significant impact on either the ICWs or the mirror mode waves.

#35

Ion Cyclotron Waves in Saturn's Equatorial Magnetosphere: Cassini Observations and Hybrid Modeling

Zachary Meeks, Lucas Liuzzo, Sven Simon

* Georgia Institute of Technology

Abstract

We apply data analysis techniques and hybrid (kinetic ions, fluid electrons) modeling to study the generation of ion cyclotron waves (ICWs) in Saturn's equatorial magnetosphere. Based on Cassini magnetic field data, we determine the amplitudes of all ion cyclotron waves detected in Saturn's equatorial magnetosphere and discuss the L-Shell and Local Time dependence of the ICW amplitude. We then apply the hybrid model to convert the observed wave amplitudes into a profile of the local ion production rate. Previously, this conversion has been done exclusively at the orbit of Enceladus (Cowee et al. (2009)), but we expand this survey to the complete occurrence realm of ion cyclotron waves in Saturn's equatorial magnetosphere (between L=3.5 and L=9.5). In doing so, we provide a relationship between the observed ion cyclotron wave amplitude and ion production rate between the orbits of Enceladus and Rhea, which we use to characterize the sources of plasma in the Saturnian system.

#36

The distribution of water-group neutrals in Saturn's Magnetosphere

H. Todd Smith, John D. Richardson

* Johns Hopkins University Applied Physics Laboratory

Abstract

Saturn's magnetosphere is unique in that the plumes from the small icy moon, Enceladus, serve at the primary source for heavy particles in Saturn's magnetosphere. The resulting co-orbiting neutral particles interact with ions, electrons, photons and other neutral particles to generate separate H2O, OH and O tori. Characterization of these toroidal distributions is essential for understanding Saturn magnetospheric sources, composition and dynamics. Unfortunately, limited direct observations of these features are available so modeling is required. A significant modeling challenge involves ensuring that either the plasma and neutral particle populations are not simply input conditions but can provide feedback to each population (i.e. are self-consistent). Jurac and Richardson (2005) executed such a self-consistent model however this research was performed prior to the return of Cassini data. In a similar fashion, we have coupled a 3-D neutral particle model (Smith et al. 2004, 2005, 2006, 2007, 2009, 2010) with a plasma transport model (Richardson 1998; Richardson & Jurac 2004) to develop a self-consistent model which is constrained by all available Cassini observations and current findings on Saturn's magnetosphere and the Enceladus plume source resulting in much more accurate neutral particle distributions. Here we present preliminary results showing the distribution of the Enceladus-generated neutral tori and the impact of plume source variability on these distributions.

#37

Constraining ion outflows at Rhea

R. T. Desai, G. H. Jones, L. H. Regoli, M. M. Cowee, A. J. Coates

* UCL-MSSL

Abstract

Rhea is Saturn's largest icy moon and hosts an oxygen and carbon-dioxide atmosphere as was detected when Cassini observed positive and negative pickup ions and an extended neutral exosphere. These pickup ions form current systems which impact the moons plasma interaction and are a key diagnostics of the moon's sputter-induced atmosphere and surface. During the first Cassini-Rhea encounter (R1), positively and negatively charged pickup ions were observed outflowing from the moon whereas on the subsequent more distant wake encounter (R1.5) only positively charged pickup ions were observed. Here, using an updated model of Cassini's Electron Spectrometer response function, we are able to estimate the outward flux of negatively charged pickup ions, the first time such a plasma population has been constrained. Using test-particle simulations we trace both the positive and negative particles back to Rhea's exobase to better understand their production and loss processes and the extent to which this process mass loads Saturn's inner magnetosphere. Furthermore, we use hybrid simulations to examine whether the calculated pickup ion densities could generate observable ion cyclotron wave activity.

#38

Enceladus Plasma and Dust Environment

I.A.D. Engelhardt, J.-E. Wahlund, D.J. Andrews, A.I. Eriksson, S. Ye, W.S. Kurth, D.A. Gurnett, M.W. Morooka, W.M. Farrell, M.K. Dougherty

* Swedish Institute of Space Physics

Abstract

We present the results of the PSS paper "Plasma regions, charged dust and field-aligned currents near Enceladus" [Engelhardt et al. 2015] of the dust environment in the vicinity of Enceladus, Saturn's icy moon using RPWS (radio and plasma wave science) and MAG (magnetometer) instrument package. There exist main distinct plasma and dust regions around Enceladus. These are (1) the plume region, with neutral gas, plasma and charged dust with a distinct (2) edge boundary region. Specifically the observations of the (3) dust trail, downstream plasma region, both seen in ion and electron densities as well as presence of charged dust. The dust in these regions is in equilibrium with the surrounding plasma. This leads to the dust particles being negatively charged by attracting free electrons. The dust distribution follows a simple power law. Furthermore the magnetic field infers strong magnetic field-aligned currents at the geometrical edge of Enceladus.

#39

Quantifying momentum transport at Saturn's magnetopause boundary

Brandon Burkholder, Peter Delamere, Xuanye Ma

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Abstract

In terms of comparative magnetospheres, how do different features of the solar wind-magnetosphere interaction scale with the properties of the magnetospheric obstacle? Is the solar wind interaction with Earth similar to that at Jupiter and Saturn, or does the Dungey cycle of large scale reconnection give way to small scale, intermittent reconnection, generating tangential drag at the magnetopause boundary? To understand the influence of a viscous-like interaction akin to that described by Axford and Hines [1961], it is crucial to quantify mass and momentum transport rates across the solar wind-magnetosphere boundary. Using ion moments calculated from Cassini plasma data in Saturn's magnetosheath, we obtain an approximate picture of what the magnetosheath looks like as a function of radial distance by performing temporal averages. We find a significant local time dependent asymmetry in the azimuthal component of flow adjacent to the magnetopause boundary, which disappears near the bow shock. We interpret this asymmetry as a consequence of the local time asymmetric flow shears, which affect the solar wind interaction with Saturn's corotational magnetodisc. We also analyze the flow properties in the low-latitude boundary layer to further quantify the effects of momentum transport at the magnetopause boundary.

#40

Field-aligned currents in Saturn's magnetosphere: Comparison of subcorotation and PPO-related components between Saturn southern summer and northern spring

Thomas Bradley, Stanley Cowley, Igor Alexeev, Emma Bunce, Gabrielle Provan, Gregory Hunt, Samuel Wharton, Michelle Dougherty

* University of Leicester

Abstract

Previous analyses of field-aligned currents in Saturn's magnetosphere using Cassini magnetic field data have focused on data from two intervals of highly inclined spacecraft orbits during late Saturn southern summer, in 2006/7 and 2008 [e.g., Talboys et al., 2009, 2011; Southwood and Kivelson, 2009]. Most recently, these data have been analysed to separate the effects of the rotating "planetary period oscillation" (PPO) currents in the northern and southern hemispheres from the PPO-independent current arising from plasma subcorotation [Hunt et al., 2014, 2015, 2016]. Here we carry through a related analysis of the magnetic field data obtained during the third interval of inclined Cassini orbits during Saturn northern spring, in 2012/13, and compare the current profiles with those obtained previously during late southern summer. We show the presence of strong seasonal effects in the subcorotation currents poleward of the open-closed field boundary, while the PPO-related currents remain similar in form though of slightly lesser magnitude during northern spring than in southern summer.

#41

Investigation of the electron density close to the rings of Saturn and Prediction of the F-ring plasma characteristics

George Xystouris, Michiko Morooka, Jan-Erik Wahlund, Mika Holmberg, Ann Persoon

* IRFU

Abstract

Since Cassini's arrival at Saturn, more than ten years of data have been collected, and the characteristics of the magnetospheric plasma have been studied thoroughly. Persoon et al. [2013] made an electron density model based on the f_UHR data. The model shows that the electron density has a local maximum near the Enceladus, which is a dominant plasma source, and decreases with increasing distances as the plasma is centrifugally transported outward. However, the electron densities in some individual orbits are not in agreement with the model, and continue to increase toward the planet even inside the Enceladus orbital distance. This could be an indication of an additional plasma source inside 4Rs [Persoon et al., 2015]. In this study we used the electron density data obtained by Cassini's Langmuir Probe (RPWS/LP) to investigate the electron density in the plasma disk ($z < |0.05Rs|$, $r<7Rs$). We used data from July 2004 (SOI) to January 2016 (Orbit 231) to statistically investigate both beyond 4Rs and inside 4Rs. We found that the general characteristics of the electron density are similar to the model by Persoon et al. [2013], although the model parameters describing the density maxima and the density gradient had slight differences. The discrepancies can be due to the measurement limitations in both LP and f_UHB. We also found a dawn-dusk asymmetry in the electron density inside 5Rs. We discuss the possible cause of the asymmetry.

#42

Characterizing Plasma Waves during Cassini's F ring and Proximal Orbits

Ali Sulaiman, William Kurth, Donald Gurnett, Michel Moncuquet, Ann Persoon, David Píša, George Hospodarsky

* University of Iowa

Abstract

At the end of 2016, the Cassini spacecraft initiated the final phase of its 13-year tour of Saturn. This comprises two sets of highly-inclined orbits with perikrones at the outer F ring and the inner D ring, thus giving unprecedented coverage of the Saturnian environment. Clear and abrupt onset and cessation of plasma waves are observed in these regions of unique conditions; from profoundly quasi-periodic auroral hiss well below the electron cyclotron frequency to intense Bernstein mode emissions above. To further characterize the properties of these waves, we attempt to constrain the upper hybrid (and thus plasma) frequency through the detection of quasi-thermal noise emissions near the ring plane. Finally, this work compares and contrasts emissions with orbits of previous years and aims to deliver the final pieces of the most complete picture of plasma waves in the Saturnian environment.

#43

The Kronian Magnetotail X-line: A Multi-Instrument Perspective

Andrew Smith, Caitriona Jackman, Michelle Thomsen

* University of Southampton

Abstract

Reconnection within Saturn's planetary magnetotail reconfigures the magnetic field: resulting in local plasma heating and the ejection of mass from the magnetosphere. The site at which this occurs is known as the x-line. Planetward of the x-line a spacecraft may observe a dipolarization as the newly reconnected field lines sweep back towards the planet. Tailward of the x-line the spacecraft may encounter plasmoids; the structures formed of the freshly disconnected mass and field. We used an extensive catalogue of plasmoids and dipolarizations from Saturn's magnetotail to locate intervals where these tailward and planetward structures were observed in quick succession. Such intervals were used as a basis for examining the reconnection X-line indirectly. Cassini plasma data were then analyzed, both to confirm the interpretation and to provide information on the plasma flow velocity and composition. Potential internal and external influences of the X-line locations are discussed.

#44

Solar Energetic Protons (SEP) as tracers of enhanced solar wind conditions upstream of Saturn's magnetosphere: event list and applications

Elias Roussos, Caitriona Jackman, Michelle Thomsen, Chris Paranicas, William Kurth, Sarah Badman, Norbert Krupp, Peter Kollmann, Aikaterini Radioti

* Max Planck Institute for Solar System Research

Abstract

Observations of Solar Energetic Proton (SEP) events by Cassini's MIMI/LEMMS instrument can be used to trace enhanced solar wind conditions at Saturn. SEP protons can be easily distinguished from magnetospheric ions, particularly at the MeV energy range. In addition, these ions can easily penetrate into the middle magnetosphere so that an SEP may be observed even if Cassini is not situated in the solar wind. A survey of the MIMI/LEMMS dataset between 2004 and 2016 resulted in the identification of 46 SEPs, the properties of which can be used in single case studies or statistical investigations of Saturn's magnetospheric response to extreme solar wind conditions. We use the event catalogue to demonstrate that transient electron and ion radiation belts in Saturn's magnetosphere form due to SEP-induced magnetospheric convection and that an SEP of day 332/2013 was the definite source of a strong magnetospheric compression and open flux loading in the magnetotail.

#45

Preliminary results from the Cassini Cosmic Dust Analyser during the Grand Finale Mission

Hsiang-Wen Hsu, Nicolas Altobelli, Marcia Burton, Mihaly Horanyi, Sascha Kempf, Nozair Khawaja, Georg, Moragas-Klostermeyer, Frank Postberg, Juergen Schmidt, Martin Seiss, Frank Spahn, Ralf Srama

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Abstract

The Cassini Grand Finale Mission provides brand new opportunities to explore the environment in the vicinity of Saturn and its main rings. With periapses of around 2.5 Saturn radii during the ring grazing orbits (2016/12-2017/04), CDA found that the inner edge of the E ring vertically extends about 1 Saturn radius away from the ring plane. Another dust population concentrated near the ring plane with a scale height of 1,000 km was measured repeatedly and is likely originated from local source(s). For the Grand Finale dives (2017/04-2017/09), one of the most important goal is to characterize the composition of the main rings. The measurements are planned for both large particles near the ring plane, as well as nanodust populations at the south latitudes. These unique measurements will shed lights on the origin of the main rings and how they interact with the host planet.

#46

Interhemispheric asymmetries in Saturn's aurora

Sarah Badman, Laurent Lamy, Renee Prangé, John Clarke, Philippe Zarka, Baptiste Cecconi, Bill Kurth, Don Mitchell, Wayne Pryor, Frank Crary, Ulyana Dyudina, Emma Bunce, Marcia Burton, Michele Dougherty, Katerina Radioti, Jon Nichols, Henrik Melin, Joe Kinrade, Greg Hunt

* Lancaster University

Abstract

In summer 2016 Saturn's UV aurorae were observed simultaneously in the northern, summer hemisphere by the Hubble Space Telescope and the southern, winter hemisphere by Cassini. For the first time, the full auroral region was visible in both hemispheres allowing the nightside auroral morphology to be examined as well as the dayside. We find significant differences in the relative auroral intensities between the two hemispheres, particularly in the most poleward arcs observed under more active magnetospheric conditions. We propose that these asymmetries could be driven by inter-hemispheric field-aligned currents, or, considering the high latitude extent of some features, in association with enhanced, persistent auroral precipitation on newly-reconnected field lines under IMF B_Y dominated conditions.

#47
The Atmosphere of Pluto: Synthesis of Results from the New Horizons Mission

Darrell F. Strobel, Xun Zhu, ALICE (Leslie Young, Josh Kammer, Andrew Steffl et al.) & REX (Dave Hinson et al.)Teams

* Johns Hopkins University

Abstract

On 14 July 2015, NASA's New Horizons spacecraft observed an ultraviolet solar occultation of Pluto's atmosphere with its ALICE ultraviolet spectrograph and performed a radio occultation that sounded Pluto's atmosphere down to the surface with radio signals transmitted simultaneously by four antennas of the NASA Deep Space Network. From the solar occultation data line-of-sight (los) optical depths that yield los column densities for 5 molecular species, and extinction coefficients for haze. The radio occultation data yield N2 number density, pressure, and temperature profiles from the surface to about 110 km of altitude at two diametric points on the planet. This talk presents a synthesis of the results from these two occultations. We find a very stable, spherically symmetry, lower atmosphere, with well-mixed portion restricted to a planetary boundary layer (surface to 5 km), peak temperature of 106 K at 25 km, cold isothermal temperature 65-68 K in Pluto's upper atmosphere, and inferred CH4 surface mixing ratio 0.3-0.5%. The inferred enhanced Jeans escape rates are 5-7 x 1022 N2 s-1 and 5-8 x 1025 CH4 s-1 at the exobase (r 2900 km, where the Kn = 0.7). All numbers subject to change!

#48
Joint Europa Mission (JEM) : A multi-scale study of Europa to characterize its habitability and search for life

Nicolas Andre, Michel Blanc, Olga Prieto Ballesteros, John F. Cooper, and the JEM proposal Team

* IRAP/CNRS

Abstract

Europa is the closest and probably the most promising target to perform a comprehensive characterization of habitability and search for extant life. We propose that NASA and ESA join forces to design an ambitious planetary mission JEM (Joint Europa Mission) to reach this objective. JEM will be assigned the following overarching goal: Understand Europa as a complex system responding to Jupiter system forcing, characterize the habitability of its potential biosphere, and search for life in its surface, sub-surface and exosphere. Our observation strategy to address these goals will combine three scientific measurement sequences: measurements on a high-latitude, low-latitude Europan orbit providing a continuous and global mapping of planetary fields (magnetic and gravity) and of the neutral and charged environment during a period of three months; in-situ measurements at the surface, using a soft lander operating during 35 days, to search for bio-signatures at the surface and sub-surface and operate a geophysical station; measurements of the chemical composition of the very low exosphere and plumes in search for biomolecules. We propose an innovative distribution of roles to make JEM an appealing and affordable joint venture for the two agencies: while NASA would provide an SLS launcher, the lander stack and mission operations, ESA would provide the carrier-orbiter-relay platform.

#49

Radiation-induced background noise for Channel Electron Multipliers at the orbit of the Galilean moons from Galileo PLS measurements

Nicolas André, William Paterson, Andréi Fedorov, Edward Sittler, Nicholaos Paschalidis, John Cooper

* IRAP/CNRS

Abstract

Charged particle instruments include electron multiplier detectors that are subject to increased transient noise, long-term degradation, and even potential failure due to the substantial fluxes of high-energy particles that penetrate the instrument. The most commonly used electron multiplier detectors are Multi-Channel Plate (MCP) and Channel Electron Multiplier (CEM). The efficiency of MCPs and CEMs detectors against high-energy particles is not well known, with limited estimates available in the literature. This makes it complicated to reliably predict the Signal to Noise ratio of charged particle instruments, and, hence, ensure that the instruments will return useful scientific data when operated for example at Jupiter. Here, we use real measurements from Galileo PLS to derive the background noise measured by CEMs in the Jovian environment. These measurements are used in combination with Geant4 simulations in order to estimate the efficiency of CEMs against high-energy electrons.

#50

Small Satellite Missions to Explore Jupiter's Magnetosphere

Frank Crary, George Clarke, Robert Ebert, Frederic Allegrini, Fran Bagenal, Chip Beebe, Ian Cohen, Peter Delamere, Mihir Desai, Don George, John Hanley, George Ho, Peter Kollmann, Neil Murphy, Chris Paranicas, Abigail Rymer, Todd Smith, Marissa Vogt, Aron Wolf

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Abstract

Terrestrial experience has shown that small spacecraft can make critical measurements. Small (<200 kg), focused spacecraft are also viable for Jovian magnetospheric studies. Small spacecraft, in an era where flagship missions are becoming narrowly focused, provide opportunities for magnetospheric studies which would be otherwise unfeasible.

To illustrate this, we describe three concepts: 1) Jupiter Orbiters Like THEMIS (JOLT), a Discovery-sized mission, using three or four 150 kg spacecraft, to study the magnetotail. 2) JUpiter MagnetosPheric boundary ExploreR (JUMPER), a single 180 kg spacecraft, to study the magnetospheric boundaries, combined with solar wind monitoring and remote sensing. 3) The Creation, History and Acceleration in the Radiation-heavy, Galilean Environment (CHARGE) concept illustrates how even smaller spacecraft (<100 kg) would address focused questions in the Io plasma torus. Even nanosatellites or CubeSats, launched in association with a larger mission.

#51

CubeSat project for the observation of Jupiter's decametric radio emissions

Kazumasa Imai, Lkhagvadorj Sukhtsoodol, Mizuki Ando, Nobuto Hirakoso, KOSEN-Space-Renkei Group

* Kochi National College of Technology

Abstract

The development of a nano satellite (CubeSat) for Jupiter's decametric radio observation is made by the collaboration with 8 colleges that belong to KOSEN-Space-Renkei Group. The students and teachers have been collaborating to develop the 2U-size CubeSat. This CubeSat is being considered to be launched from the International Space Station (ISS). The duration of the possible observation is estimated to be more than 50 days. During this period we are considering the measurement of the delay time between the CubeSat and ground observatories for the detection of Jovian S-bursts. The delay time is determined by a cross-correlation method and will reveal very important information about the beaming model parameters of Jupiter's radio emissions. We show the design of the CubeSat for the observation of Jupiter's radio emissions, including the data acquisition system using a Raspberry Pi Zero with a GPS module, the deployment of the antenna system, and the software defined receiver.

#52

Planetary magnetospheric studies with the Large Ultra-Violet Optical Infrared (LUVOIR) surveyor.

Walter Harris (University of Arizona), Britney Schmidt (Georgia Tech University), Geronimo Villanueva (Goddard Space Flight Center), and the LUVOIR solar system science definition team

* University of Arizona

Abstract

LUVOIR is a large aperture space observatory concept currently under NASA study that is intended to address the science goals highlighted in the NASA 2013 Astrophysics Roadmap "Enduring Quests, Daring Visions" and the recent AURA report "From Cosmic Births to Living Earths". The LUVOIR platform is envisioned as a 15 m, diffraction limited (to 400 nm) telescope located at L2 with a serviceable suite of advanced-technology instruments providing imaging, spectroscopic, and polarimetric measurements over the 100-3000 nm spectral range with up to 100x the sensitivity and dynamic range of HST. The science case for LUVOIR includes the study of the universe on all scales and will place significant emphasis on the origins, evolution, and current properties of our solar system. The solar system science sub-group of the LUVOIR science and technology definition team (STDT) has identified Sun-planet interactions as one of the key components of this program. In this presentation we will describe the proposed capabilities of LUVOIR and discuss how they can be utilized to study magnetospheric processes at the giant planets and their satellites, with the goal of engaging the scientific community in the development of a robust technical and scientific discussion in the eventual concept study report.

#53
Energy conversion regions in the plasma around comets

Jesper Lindkvist, Maria Hamrin, Herbert Gunell, Hans Nilsson, Timo Pitkänen, Cyril Simon Wedlund, Etienne Behar

* Umeå University

Abstract

Jupiter family comets like 67P/Churyumov-Gerasimenko (target of the Rosetta mission) have a mixture of both water and carbon dioxide in their atmospheres (coma). The coma becomes ionised by processes like photoionisation or electron impact ionisation, and will be picked up by the solar wind convective electric field, thus mass-loading the solar wind. This is much like the mass-loading processes around the Galilean moons where atmospheric particles are ionised and are picked up by the convective electric field of the Jovian magnetosphere. We use a hybrid model of plasma to investigate the interaction between the comet and the solar wind. We show the energy conversion regions of the cometary atmosphere, where a shock-like structure acts as an electromagnetic generator, similar to a traditional bow shock. The electromagnetic energy is transported towards the comet nucleus, where the newly ionised particles are accelerated, and thus acts as an electromagnetic load.

Poster Session 2

Thursday, 15 June

#1

Radio occultations of the Io plasma torus with the Juno spacecraft: A study of feasibility

Phillip H. Phipps, Paul Withers

* Boston University

Abstract

Volcanoes on the innermost Galilean satellite, Io, release material into the surrounding area in Jupiter's magnetosphere where it is subsequently ionized. The material becomes trapped in Jupiter's magnetic field and distributed into a torus around Jupiter, called the Io plasma torus. On each perijove of the Juno spacecraft the line of sight between Juno and the Earth passes through the Io plasma torus. We show that a radio occultation will occur during the perijove pass of the spacecraft. It is also show that the effect on the radio signal passing through the Io plasma torus can be used to determine the torus total electron content, assuming 36 second integration times. From the total electron content we find that Io plasma torus parameters can be determined with 10 % uncertainties.

#2

Radio emission from the Ganymede-Jupiter interaction and consequence for radio emissions from exoplanets

Philippe Zarka, Manilo Soares-Marques, Corentin Louis, Vladimir Ryabov, Laurent Lamy, Ezequiel Echer , Baptiste Cecconi, Sébastien Hess, Andrée Coffre, Laurent Denis

* Observatoire de Paris, CNRS, PSL

Abstract

Analysis of a catalog of 26 years of radio decameter observations from Jupiter in Nançay (France) allowed us to detect unambiguously the radio emissions resulting from the Ganymede-Jupiter interaction. The duration and power of the 189 events detected suggest sporadic reconnection with an average radio power released in the Ganymede-Jupiter decameter emission 15 times smaller than in the Io-Jupiter one. This compares well with the ratio of the magnetic power (Poynting flux) dissipated at the Ganymede-Jupiter and Io-Jupiter interactions, confirming the radio-magnetic Bode's law of Zarka et al. (2001), that serves as a basis for predicting exoplanetary radio emissions. Constraints imposed by the Ganymede-Jupiter radio emission on Jovian magnetic field models are also discussed.

#3

Detection of Jupiter decametric emissions controlled by Europa and Ganymede with Voyager/PRA and Cassini/RPWS

C. K. Louis, L. Lamy, P. Zarka, B. Cecconi, and S. L. G. Hess

* LESIA, Observatoire de Paris

Abstract

The Jovian high latitude radio emissions produced by Jupiter's magnetosphere extend from a few kHz to 40 MHz. Part of the decametric emissions are not auroral but driven by the Galilean moon Io (Io-DAM), and we expect the other Galilean moons Europa, Ganymede and Callisto to drive jovian radio emissions too. Indeed UV emissions induced by those three first Galilean moons exist. We used a simulation code named ExPRES (Exoplanetary and Planetary Radio Emissions Simulator) to predict dynamic spectra (time-frequency spectograms) for the radio emissions controlled by the four Galilean moons. Then we compared the simulations to the Voyager (PRA instrument) and Cassini (RPWS instrument) data acquired during their flybys of Jupiter (in 1979, and between 2000 and 2003, respectively). We detected Jupiter DAM emissions controlled by Europa (130 events) and Ganymede (96 events). The statistical analysis of those detections allows us to describe the average properties of the Europa-DAM and Ganymede-DAM emissions (spectral, temporal variability, occurrence in a diagram satellite phase versus central meridian longitude).

#4

A new physical model of the electron radiation belts of Jupiter inside Europa's orbit: on the key role of the plasma waves above the orbit of Io

Quentin Nénon, Angélica Sicard, Sébastien Bourdarie

* ONERA, The French Aerospace Lab

Abstract

From 1998 to 2004, ONERA has adapted its 3D physical model of the Earth radiation belts, Salammbo, to the Jovian electron belts. An upgraded Jupiter-Salammbo model that extends from the Jovian surface to the orbit of Europa will be presented. The model now takes into account the gyro-resonant interaction with the plasma waves detected by Galileo above the orbit of Io. It also now relies on a realistic outer boundary condition (i.e. electron injection near Europa), well constrained by the in-situ flux measurements and consistent with the empirical models. The validation of Salammbo against in-situ and remote (synchrotron emission) observations will be discussed, as the key role of the plasma waves in the Jovian electron belts. Finally, the benefits of developing a physical model of the trapped protons to further constrain the physical processes shaping the electron belts, in particular the radial diffusion and sweeping effects by the moons and dust rings, will be pointed out.

#5

An updated physical model of the proton radiation belts of Jupiter inside Europa's orbit

Angélica Sicard, Quentin Nénon

* ONERA, The French Aerospace Lab

Abstract

In 2004, ONERA has developed a 3D physical proton model of the Jovian radiation belts, Salammbo, inside Io orbit. An updated Jupiter-Salammbo proton model that extends from the Jovian surface to the orbit of Europa will be presented. The model takes into account the major physical processes governing the Jovian radiation belts: radial diffusion, interaction with moons and rings, charge exchange, interaction with cold plasma. . . . The relative importance of each physical process will be investigated. It also now relies on a realistic outer boundary condition near Europa, well constrained by the in-situ flux measurements (Galileo, Voyager, Pioneer) and consistent with the empirical models. The validation of this updated Salammbo proton model against in-situ measurements will be discussed.

#6

The Jovian Current Sheet as Observed by Juno's JADE

R.J. Wilson, F. Bagenal, P.W. Valek, D.J. McComas, S.J. Bolton, F. Allegrini, N.G. Angold, J.E.P. Connerney, K. Chae, R.W. Ebert, T.K. Kim, S. Levin, C.E. Loeffler, P. Louarn, D.A. Ranquist, M. Reno, J.R. Szalay, M.F. Thomsen, S. Weidner, J.L. Zink

* LASP, U. Colorado

Abstract

The Juno spacecraft is on a polar orbit around Jupiter, where the inbound trajectory to each perijove (PJ) is closer to equatorial regions than the outbound. The JADE suite of sensors on Juno measures the thermal plasma (0.1 to 100 keV/q for electrons and 0.01 to 50 keV/q for ions) and was only on around perijove for PJ1 to PJ3. For the first time, at PJ4, JADE turned on and stayed on for the entire orbit. During 2017-082 to 2017-085 (inbound towards PJ5, which is 2017-086) multiple current sheet crossing were observed where both the protons and heavy ions (O^{n+} and S^{n+}) were within the JADE energy range. Ion counts are few when JADE was outside the current sheet (and predominantly protons, but plausible that heavier ions are above JADE's energy range). However, during current sheet encounters the heavy ions dominate the denser plasma. We investigate the plasma properties of these initial JADE observed current sheet encounters.

#7

Statistical analyses of Jovian Io and non-Io decametric emissions using the new Nancay 26-year catalog

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Abstract

Recently a catalog of Nançay Decametric Array observations of Jovian radio emissions has been compiled. The catalog is based on digital data from 1990 to 2015. Jovian decametric (DAM) emissions have been classified in Io and non emission types, and in the different sources ("A", "B", "C", "D"). In this work, statistical analyses of these emissions are presented. Emission occurrence rate, duration, maximum frequency and polarization are analysed. Further, new emission types have been classified (Io-A", Io-B' and non-Io-D). The results obtained with this new catalog can be used for a large number of studies of Jupiter's magnetosphere, such as long-term variations, solar wind-Jupiter magnetosphere coupling, cooperative studies with spacecraft (e.g, Galileo, Cassini flyby, Juno) and other observations and models.

#8

Variations of Jupiter's auroral radio emission in relation to magnetospheric plasma enhancement event

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Abstract

Around Jupiter's oppositions to the earth after 2014, remote observations for Jupiter had been made continuously by the Japanese space telescope satellite HISAKI in the UV range. In particular in the 2015 campaign period, sudden enhancement of Iogenic plasma emissions occurred in the middle of Jan. and the enhancement had lasted for more than two months. This interesting phenomenon would give a valuable opportunity to study what elements and/or processes affect magnetosphere's variations. We have investigated occurrence features of Jupiter's auroral radio emissions in the hectometric and decametric wave ranges (HOM and DAM, respectively) and have examined their relations with the Iogenic plasma variations using the WIND/WAVES radio wave data. From the analysis, it is found that the both radio emissions showed following characteristic variations; occurrence probability/intensity of HOM has increased, and the recurrence periodicity of non Io-DAM's "QP burst" (Panchenko et al., GRL, 2010; PSS, 2013) has been shorter during the plasma enhance period. This result in HOM is opposite to the precedent study by Yoneda et al. (GRL, 2010). As for the result in DAM, variation of the recurrency for the particular period is a new aspect in this "QP" burst. In the presentation, we will introduce the variation features in HOM and DAM precisely, and would like to discuss expected source region and processes driving these characteristic radio wave variations.

#9

Energetic ions and electrons inward of Jupiter's rings from Juno/JEDI

P. Kollmann, C. Paranicas, G. Clark, A. M. Rymer, B. H. Mauk, D.K. Haggerty, L. Brown, J. Peachey, D. Santos-Costa, J. Saur., J. E. P. Connerney, F. Allegrini, P. Valek, W. S. Kurth, G. R. Gladstone, S. Levin, S. Bolton

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Abstract

Juno is the first spacecraft that repeatedly passes close to Jupiter's surface. Its closest approach distances are around 1.06RJ from Jupiter's center. Juno's orbit makes it uniquely suited to study the innermost region of Jupiter's magnetosphere, including a region that magnetically connects near the rings. The JEDI instrument we use measures charged particles in the keV to MeV range and distinguishes ion species.Already Juno's first science pass revealed the existence of an ion population inward and throughout Jupiter's rings. The energy spectrum is rising at hundreds of keV, which is consistent with the ions being supplied by energetic neutral atoms that are produced in the Io & Europa neutral cloud and stripped in Jupiter's high atmosphere. This seems to be a common process since it is also thought to occur at Earth and Saturn. The innermost ion belt is time or longitude dependent, since it is not seen in all of Juno's passes. In the absence of ions, an electron population can be measured. While there can be ambiguity in the JEDI data between the detection of electrons and ions, we confirm that these measurements are dominated by electrons. Electrons were previously measured throughout the magnetosphere to have a spectrum that rolls over in the MeV range. The electron spectra near Jupiter show a similar shape but roll over in the hundreds of keV range, indicating that their origin and history differs.

#10

H/H2 Brightness Ratio of Jupiter Aurora

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Abstract

The far-ultraviolet (FUV) aurora seen on giant planets is directly produced by the precipitating auroral electrons. An analysis of Saturn's aurorae taken by the Ultraviolet Imaging Spectrograph instrument onboard the Cassini spacecraft showed that the brightness ratio of H Lyman-α to H2 auroral emissions statistically decreases with the brightness of H2 taken as a proxy of the energy of precipitating electrons. This ratio is suggested to provide a sensitive diagnosis of auroral electron energy from modeling studies, and the measurement was then investigated in details for the Saturn's case to show that the brightness ratio provides low energy electrons (typically lower than 10 keV), in contrast with the FUV color ratio (CR) method which provides the energy of electrons $>$10 keV. The H/H2 ratio would be also useful for the Jupiter case to investigate the role of low energy auroral electrons, and we investigated the relationship of Jupiter auroral observed by the Hubble Space Telescope. The H/H2 brightness ratio does not show any clear relationship with the FUV CR which is sensitive to more energetic electrons. Compared to the same analysis applied for Saturn aurora, we found that the relationship for Jupiter mainly shows decreasing flux with increasing energy without acceleration features, which would reflect the different plasma environments.

#11

Studying Jupiter's X-ray aurora with Chandra

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Abstract

The Chandra space telescope has recently conducted a number of campaigns to observe Jupiter's X-ray aurora. We report on results from two of these campaigns. The first campaign took place in summer 2016 while the Juno spacecraft was upstream of the planet sampling the solar wind, and the second campaign covers spring and summer 2017, with Chandra observations matched to the times when Juno was at apojove and predicted to be near the dawn flank magnetopause. We report on the X-ray observations including intensities and periodicities of auroral X-ray emissions. We aim to examine possible drivers of X-ray emission including reconnection and the Kelvin-Helmholtz instability and to explore the role of the solar wind in controlling the emissions.

#12

Juno/JEDI observations of energetic ion precipitation in the Jovian auroral region

D. K. Haggerty, B. H. Mauk, C. Paranicas, G. Clark, P. Kollmann, A. M. Rymer, S. J. Bolton, J. E. P. Connerney, S. M. Levin.

* JHU-APL

Abstract

The Juno spacecraft's polar orbit provides an exceptional opportunity to study auroral processes in the largest and most dynamic auroral region in the solar system. The Jupiter Energetic particle Detector Instruments (JEDI) have SSD telescopes with multiple look directions and additional time-of-flight capabilities to measure ions and electrons from 6 keV to 20 MeV. These instruments resolve major ion species beginning at 30 keV/n, with coarser mass resolution for lower energy ions. JEDI instruments observed energetic heavy ions up to 20 MeV precipitating into the auroral regions during the first few Juno perijoves that have occurred to date, but the intensity and spatial location vary greatly from one pass to the next. Precipitating energetic heavy ions are believed to be the source population for Jupiter's x-ray aurora. We report on the new findings of energetic heavy ions from the first few Juno orbits with an emphasis on the auroral regions. We will also compare and contrast the observations from each of the auroral passes.

#13

The spatial distribution of atomic oxygen emission at 130.4 nm around Io's orbit observed by Hisaki/EXCEED.

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Abstract

The atmosphere of a Jovian satellite Io has been thought to be mainly by volcanism and sublimation of frost. Dominant atmospheric gases are sulfur dioxide, and dissociative product such as atomic oxygen and sulfur, which are produced mainly by electron impact dissociation and photolysis. Neutral oxygen escape from exobase to neutral clouds ($>$ 5.8 Io radius) mainly by atmospheric sputtering. However, it was not understood the characteristics of spatial distribution of atomic oxygen escaping from Io. we investigated Io phase angle (IPA) dependence of atomic oxygen emission at 130.4 nm averaged for the distance range of 4.5-6.5 Jupiter radius from Jupiter in the dawn and dusk sides, respectively during volcanically quiet period (DOY -35 -1). Then, we found following two important observation fact. First, weak atomic oxygen emission (4-6 Rayleighs (R)) continuously exists on both dawn and dusk sides not depending on the phase angle. This suggests that small amount of atomic oxygen distributes uniformly along the Io's orbit. Second, the emission averaged between IPA 60-90 degrees (14.0 R) was larger than that between IPA 90-120 degrees (10.5 R) on the dawn side, there was a similar tendency on the dusk side. We can explain this difference if the large amount of atomic oxygen spread inward and ahead of Io's orbit and shape like banana expected by the model of atomic oxygen neutral clouds such as Smyth and Marconi [2003].

#14

Kinetic Alfven wave propagation and electron trapping in the Io plasma torus

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Abstract

Electron energization by dispersive Alfven waves (either inertial or kinetic) is associated with Alfvenic aurora in the terrestrial magnetosphere and is assumed to play a role at Jupiter as well since Io's interaction with the Jupiter magnetosphere is a large source of Alfven wave energy. In the terrestrial plasma sheet, the kinetic Alfven wave (KAW) regime dominates and electrons with speeds close to the phase speed of the wave can resonantly interact with the wave and become trapped in the wave potential. This trapping leads to an elongated core to the electron distribution function parallel to the background magnetic field that is evident in both observations and simulations. The Io plasma torus is also a region where KAWs are thought to be prevalent and where important differences, from the terrestrial example, include the dominance of heavy ions and the trapping of wave energy in the steep density gradients at the torus boundaries. In this presentation, we summarize and compare efforts to study KAW propagation in the torus using both traditional hybrid (kinetic ion, fluid electron) and gyrofluid kinetic-electron models. Using the latter, we also address electron trapping in the KAWs and find that trapping within the wave increases with ion mass and we track the evolution of the trapped electron population as the wave propagates through the steep density gradients at the torus boundary.

#15
The Juno Investigation of Jupiter's Magnetosphere: Orbit and Science

B.A. Bolton, I.E.P. Connerney

* Artistic Sciences, Inc.

Abstract

The Juno Investigation of Jupiter's Magnetosphere: Orbit and Science B.A. Bolton (1) and I.E.P. Connerney (2,3)

1. Artistic Sciences, Inc., San Antonio, TX, USA 2. Space Research Corporation, Annapolis, MD, USA 3. Technical University of Denmark (DTU), Lyngby, Denmark

Juno is the first mission to investigate Jupiter using a close polar orbit. The Juno science goals include the study of Jupiter's polar magnetosphere, interior structure, deep atmosphere and composition. An overview of Juno's magnetospheric investigation and how the orbit explores Jupiter's polar and distant magnetosphere will be presented. Interesting and key target regions are identified as they relate to Juno results presented in other poster papers to facilitate comparison and analysis discussions.

#16
Jupiter's Plasma Sheet and Io Torus: Voyager, Galileo, Cassini, Hisaki, Juno

Fran Bagenal

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Abstract

Each mission provides a unique perspective. The Voyager flybys of Jupiter in 1979 provided a key first good look at the Io plasma torus and plasma sheet that had only been hinted at from the ground and Pioneer. Cassini gained its gravity to assist to Saturn by passing far from Jupiter but provided the first high definition measurements of the Io plasma torus UV emissions. Analysis of these emissions honed the tools for modeling the physical chemistry of the torus plasma. While hampered by a damaged antenna, Galileo's seven years at Jupiter monitored temporal variability of the system. From Earth orbit, the Hisaki satellite has been observing the Io plasma torus since 2013. By MOP, Juno will have passed five times through the system at high latitudes. In this paper we review the observations of Voyager, Cassini and Galileo of the Io plasma torus and jovian plasma sheet (in the light of current understanding) and consider the new in-sights provided by Hisaki and Juno.

#17
Linking High Latitude Ion Observations to Equatorial Sources at Jupiter

J. R. Szalay, F. Allegrini, F. Bagenal, S. Bolton, G. Clark, J. E. P. Connerney, R. W. Ebert, D. J. Gershman, W. S. Kurth, S. Levin, P. Louarn, B. Mauk, D. J. McComas, C. Paranicas, D. Ranquist, M. Reno, M. F. Thomsen, P. W. Valek, S. Weidner, R. J. Wilson

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Abstract

Plasma measurements provide some of the most critical information we have about Jupiter's magnetospheric structure and dynamics. The Juno mission carries the Jovian Auroral Distributions Experiment (JADE), which detects low energy ions (<50 keV/q) and electrons (<100 keV). JADE observed high latitude proton, oxygen, and sulfur populations when magnetically connected to the Io torus and inner/middle plasma sheet. Both the proton and heavy ion temperatures are observed to increase with increasing equatorial magnetic mapping distances from 5 jovian radii up to a plateau after 15-20 jovian radii. These populations are observed to have a high degree of variability, exhibiting 1-2 orders of magnitude differences in high latitude energy fluxes for similarly mapped observations across multiple Juno orbits. However, since there are uncertainties in both the internal field models and the correct field line mapping to the equator, these variations should be considered with those factors in mind. In this study, we examine these high latitude ion distributions in the context of their plasma sheet source distributions and compare the diversity of measurements taken by JADE amongst Juno's multiple close approaches.

#18
The Search for the Kelvin-Helmholtz Instability on Jupiter's Dawn Side Magnetopause using Juno

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Abstract

Juno's 53-day orbit spends substantial time at Jupiter's magnetopause boundary. Over the first several orbits, Juno's instruments have detected dozens of magnetopause crossings. Masters et al. (2012) found surface waves at Saturn's magnetopause by determining the boundary normal orientation of each of Cassini's crossings of the magnetopause. Similarly, we search for surface waves on Jupiter's magnetopause by using minimum variance analysis (MVA) on the magnetic field data provided by the Juno Magnetic Field Investigation (MAG). Juno's orbit is on Jupiter's dawn side, where magnetospheric corotation is in the opposite direction to magnetosheath flow, which encourages the growth of the Kelvin-Helmholtz Instability (KHI). KHI, in turn, can lead to mixing of magnetospheric and magnetosheath plasma and magnetic reconnection. Here we present the results of this study.

#19

The Commissioning of the Io Input/Output Facility (IoIO), a robotic observatory for studying Jupiter's magnetospheric response to Io's volcanic activity

Jeff Morgenthaler, Julie Rathbun

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Abstract

We have recently constructed the Io Input/Output (IoIO) facility, a small-aperture ground-based robotic observatory which will conduct nightly observations of the Io plasma torus (IPT) and the Jovian sodium nebula for the next 5 Jovian oppositions. IoIO measures the brightness and morphology of the Jovian sodium nebula to 50 Rj and the brightness and positions of the IPT ansas. The brightness of the Na nebula, together with Io IR observations contemporaneously recorded at NASA's IRTF, provide a measure of the amount of material flowing into the IPT. The brightness of the IPT ansas indicates how much material is impounded there. The east-west shift of the IPT ansas provides a measure of the amount of material flowing toward the magnetotail. We will use the relative timings of the peaks in the IPT brightness and IPT shift to determine whether or not physical processes originating in the magnetotail drive mass loss from the IPT.

#20

What impedes radial transport of material in Jupiter's inner magnetosphere?

Jeff Morgenthaler (Planetary Science Institute), Max Marconi (Prisma Basic Research)

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Abstract

The Io plasma torus (IPT) is a collection of ions trapped in Jupiter's magnetic field near Io's orbital radius. Based on estimates and modeling of the interchange instability, the residence time of IPT ions should be 10 hours. The observed residence times are 20 – 80 days. What physical mechanism is impeding radial diffusion from the IPT? Two ideas have been proposed: (1) velocity sheer impoundment of flux tube interchange and (2) ring current impoundment. In support of (2), Louarn et al. (2014) find a coincidence between Galileo observations of particle injection events, Jovian hectometric emission (HOM), and narrow-band kilometric radiation (nKOM) and propose that reconnection/reconfiguration events in the magnetotail send particle injections inward, triggering HOM. The particles erode the ring current and let IPT material leak out, triggering nKOM. We present new analyses of spectroscopic observations of Io's exospheric oxygen emission which effectively turn Io into an in situ plasma probe. Using the Smyth & Marconi semi-empirical IPT model, we show evidence of missing mass in the plasma torus in the post midnight sector during a Louarn et al. event, providing independent corroboration of the Louarn et al. picture of mass loss from the IPT and therefore the ring current impoundment mechanism.

This work is supported by NASA Outer Planets Research grants NNX11AM43G and NNX13AL08G to the Planetary Science Institute.

#21

Image processing of ground based observations of [SII] emission lines from the Io plasma torus

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Abstract

Immersed in Jupiter's magnetosphere is Io, the innermost of the Jupiter's four Galilean moons. Io is a remarkable object due to its intense volcanic activity. Io's volcanism produces a tenuous atmosphere that escapes creating the Io plasma torus (IPT), a ring of charged particles encircling Jupiter. Considering this scenario, it is reasonable to expect that the IPT torus should be affected by changes in Io's volcanism. Observations of the Jovian satellites from space-based platforms began in the early 1970s with the launch of Pioneer 10 and 11. Since then several encounters occurred with Jupiter and the Galilean satellites. Ulysses, Cassini and New Horizons took information at a distance, while Galileo had made several flybys on Io. However an outstanding question concerning the complex Io-Jupiter coupled system is how Io's volcanic activity affects the IPT variability. In this work, it is focused on [SII] 6731 Å emission lines from the IPT, obtained by ground-based observations at the MacMath-Pierce Solar Telescope in the late nineties. Here is presented the methodology developed to image/data processing of the torus and some first anlaysis of the intensity variatbility, with the aim to obtain information related to system IV.

#22

Juno Bow Shock and Magnetopause Encounters at Jupiter

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Abstract

The Juno spacecraft has crossed Jupiter's bow shock (BS) and magnetopause (MP) multiple times in the dawn sector (near 0600 Local Time), both during the approach to Jupiter and during the first five apojove periods. A survey of all of these crossings using the Juno field and particle instruments has been performed, with over 50 bow shock and 100 magnetopause crossings being detected. The BS crossings ranged from 92 to 128 RJ and the MP crossings ranged from 73 to 114 RJ. During approach, Juno initially encountered an expanding magnetosphere resulting in a single BS and MP crossing, followed a few days later by a contracting magnetosphere, resulting in seven more MP crossings and a BS crossing on the first outbound orbit at 92 RJ. The lack of BS crossings and the limited number of MP crossings during the second apojove period suggests a long period of an expanded magnetosphere, likely caused by a prolonged period of low solar wind dynamic pressure associated with a rarefaction region. Juno's encounters with these boundaries, and their apparent motion (inward or outward) will be compared to models and predictions of the shape of the Jovian magnetosphere. Solar wind propagation models will also be examined for possible correlations between the encountered boundaries and solar wind dynamics.

#23

Enhancing Jupiter's Auroral Second Oval

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Abstract

The second oval is a feature of the Jovian outer auroral emission seen as sections of discrete arcs of varying length, equatorward of the main auroral oval. This study quantifies the location and intensification of the second oval feature during sequences of images taken by the Hubble Space Telescope. Small sections of the feature can be picked out in most images, however the feature appears brighter and extended longitudinally 1-3 days after large injection signatures. The feature lies close to the latitude of the Ganymede auroral footprint. We complement the image analysis with spectral analysis of the injection and second oval signatures as well as theoretical consideration of wave-particle interactions as a possible generation mechanism. The study is particularly timely given recent JUNO JEDI and Waves results, describing where energetic particles occur and waves may grow in the Jovian magnetosphere, in addition to UVS results, describing the aurora at all longitudes.

#24

Characteristics of temporal variations in IPT and auroral emissions deduced by EXCEED

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Abstract

Jovian magnetosphere is characterized by its strong magnetic field and plasma supply by Io. It is an "internally-driven" magnetosphere with superior co-rotation compared with the solar wind. In the inner side of the Jovian magnetosphere, there is an energetically significant structure called Io plasma torus (IPT), which can be an index of the density of hot plasma. It is pointed out that auroral brightennings are correlated with the phenomenon in the middle and outer magnetosphere which is magnetically connected to the planet's pole regions. Previous study using EXCEED onboard the Hisaki spacecraft detected the phenomenon that IPT brightens in response to auroral brightenings. This suggests the existence of inward energy flow from the middle magnetosphere to the inner magnetosphere. However, it was just the discovery of several events, and statistical analysis was not done. Therefore, features of brightenings were not clarified. Thanks to the long-term and continuous observation for aurora and IPT by EXCEED, we identified dozens of brightening events, and statistically investigated the features of the brightenings. It became clear that local time dependence exists in the IPT brightenings. In addition, it was found that different type of such IPT brightening events occurred in Io's volcanic active period. This suggests the existence of multiple energy transport mechanisms between the inner and middle magnetosphere.

#25

Variation of ion and electron temperature on Io plasma torus during an outburst measured with Hisaki/EXCEED and gourd-based telescope

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Abstract

We focus on variability of electron temperature on Io plasma torus (IPT) derived from EUV diagnostics measured by space telescope Hisaki/EXCEED after a volcanic outburst in 2015, as well as ion temperatures parallel and perpendicular to the magnetic field measured from the ground-based spectroscopy. The [SII] observation of IPT was made at Haleakala Observatory from November 2014 through May 2015 with the Echelle spectrograph (R=67,000) coupled to a 40-cm telescope, which enables to enables to measure S+ temperatures parallel and perpendicular to the magnetic field. We also made observation of neutral sodium cloud as a proxy of supply of neutral particles from Io (Yoneda et al., 2015). Based on observation of neutral sodium cloud (Yoneda et al., 2015), neutral supply started to increase at around DOY= 10, was at maximum at around DOY = 50, and has backed into the initial levels at around DOY = 120. In contrast, plasma diagnostics made by Hisaki/EXCEED EUV spectroscopy indicates that hot electron fraction was less than 2 % before DOY = 50, started to increase after DOY = 50, and have reached 8(+/-1) % at DOY = 110. In addition, ion temperatures from ground-based observation started to increase after DOY=50 as similar tread of increase of hot electron fraction. Aurora sudden brightening events were also activated after DOY = 50 as increase of hot electron fraction on the plasma torus. A possible scenario will be discussed on the presentation.

#26

Ion compositions in Jupiter's magnetosphere observed by Juno JADE-I

Thomas K. Kim, P. W. Valek, D. J. McComas, F. Allegrini, N. G. Angold, F. Bagenal, S. J. Bolton, K. Chae, C. Loeffler, R. W. Ebert, S. Levin, P. Louarn, C. Pollock, D. A. Ranquist, J. R. Szalay, M. L. Reno, M. F. Thomsen, S. Weidner, R. J. Wilson, J. L. Zink

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Abstract

The Jovian Auroral Distributions Experiment Ion sensor (JADE-I) is a plasma instrument on Juno that can measure ions with energies ranging from 0.01 – 46.2 keV/q for individual ion species. However, ion species with similar mass per charge (M/Q) can create an ambiguity in determining the measured ion species. Magnetospheric plasmas at Jupiter are mostly composed of dissociation products of iogenic SO2, which include ion species with similar M/Q (e.g., O+ and S2+ both have M/Q of 16 amu/q). These ions, so called iogenic plasmas, were first observed by plasma instruments onboard previous missions (e.g., Voyager 1 and 2, Galileo, etc.). However, the relative abundance of O+ and S2+ in Jupiter's magnetosphere were only studied using physical assumptions due to the inability of the instruments to resolve the O+ and S2+. Thin carbon foils are used in the TOF section of JADE-I to produce start signals from secondary electron emission generated by interactions between the foil and incoming ions. However, these interactions can also alter the properties of the incident ions via carbon foil effects. Previous studies have shown that carbon foil effects vary depending on incident atomic species, energy, and angle. We developed a model that can characterize the carbon foil effects for Jovian magnetospheric ions measured by JADE-I. We will show ion composition analysis results on observations at high latitudes and in the plasmasheet by applying our model.

#27

Variability of Jupiter's IR H3+ aurorae during Juno approach

Luke Moore, James O'Donoghue, Henrik Melin, Tom Stallard, Chihiro Tao, Bertalan Zieger, John Clarke, Marissa F. Vogt, Tanapat Bhakyapaibul, Merav Opher, Gabor Tóth, John E. P. Connerney, Steve Levin, and Scott Bolton

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Abstract

We present ground-based observations of Jupiter's H3+ aurorae over four nights in April 2016 while the Juno spacecraft was monitoring the upstream interplanetary magnetic field. High-precision maps of auroral H3+ densities, temperatures, and radiances reveal significant variabilities in those parameters, with regions of enhanced density and emission accompanied by reduced temperature. Juno magnetometer data, combined with solar wind propagation models, suggest that a shock may have impacted Jupiter in the days preceding the observation interval, but that the solar wind was quiescent thereafter. Auroral H3+ temperatures reveal a downward temporal trend, consistent with a slowly cooling upper atmosphere, such as might follow a period of shock recovery. However, the brightest H3+ emissions are from the end of the period, April 23rd. The lack of definitive signatures in the upstream interplanetary magnetic field lends supporting evidence to the claim that this brightening event may have been driven by internal magnetospheric processes.

#28

Magnetosphere - Ionosphere - Thermosphere (MIT) coupling at Jupiter

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Abstract

Jupiter's upper atmospheric temperature is considerably higher than that predicted by Solar Extreme Ultraviolet (EUV) heating alone. Simulations incorporating magnetosphere-ionosphere coupling effects into general circulation models have, to date, struggled to reproduce the observed atmospheric temperatures under simplifying assumptions such as azimuthal symmetry and a spin-aligned dipole magnetic field. Here we present the development of a full three-dimensional thermosphere model coupled in both hemispheres to an axisymmetric magnetosphere model. This new coupled model is based on the two-dimensional MIT model presented in Yates et al., 2014. This coupled model is a critical step towards to the development of a fully coupled 3D MIT model. We discuss and compare the resulting thermospheric flows, energy balance and MI coupling currents to those presented in previous 2D MIT models.

#29

Comparison of a Physical Chemistry Model of the Io Plasma Torus with Measurements by JAXA's Hisaki Mission, NASA's Juno Mission and Other Earth-based Observations

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Abstract

Io emits volcanic gases into space at a rate of about a ton per second. The gases become ionized and trapped in Jupiter's strong magnetic field, forming a torus of plasma that emits 2 terawatts of UV emissions. Our recent work on re-analyzing UV data from Voyager, Galileo, & Cassini of the Io plasma torus has found that we can explain our observations of plasma conditions using a physical chemistry model with a neutral source of sulfur dioxide from Io (Nerney et al., 2017). We plan to continue our work by analyzing UV observations from JAXA's Hisaki mission using our spectral emission model. We will constrain the torus composition with ground based observations. The physical chemistry model (adapted from Delamere et al., 2005) will then be used to match derived plasma conditions. We will correlate the oxygen to sulfur ratio of the neutral source with volcanic eruptions to understand the change in magnetospheric plasma conditions. Our goal is to better understand and constrain both the temporal and spatial variability of the flow of mass and energy from Io's volcanic atmosphere to Jupiter's dynamic magnetosphere. Through 2017-2018 the Io plasma torus will be monitored by JAXA's Hisaki satellite and the magnetosphere mapped out by particles and fields instruments on NASA's Juno spacecraft.

#30

North and South: Simultaneous observations of both Jovian poles from Juno and the Hubble Space Telescope

Bertrand Bonfond, George R. Gladstone, Denis Grodent, , Zhonghua Yao, Jean-Claude Gérard, Thomas K. Greathouse, Maarten Versteeg, Vincent Hue, Michael W. Davis, Aikaterini Radioti, Scott J. Bolton, Steven M. Levin, John E. P. Connerney

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Abstract

On its elongated orbit, Juno flies over the poles of Jupiter every 53.5 days. The few hours before and after the perijove offer unique opportunities to observe the whole polar region from close distance. However, Juno's instruments can only observe one hemisphere at a time. Fortunately, the Hubble Space Telescope points its 2.4 m mirror toward the opposite hemisphere during some of these time intervals, providing truly simultaneous observations of both poles. We compare observations from Juno-UVS with Far-UV imaging sequences from the Hubble's Space Telescope Imaging Spectrograph (STIS). Juno-UVS acquires spectrally resolved images of 17 ms exposure every 30 s Juno spin in the 70-205 nm wavelength range, while STIS can acquire about 270 consecutive 10 s images per HST orbit in the 130-160 nm range, but without any spectral resolution. Despite some differences, these datasets are similar enough in terms of spectral coverage, temporal and spatial resolution to allow direct comparisons. On Jupiter, the magnetic field is highly asymmetric and displays significant localized anomalies. Furthermore, most processes leading to auroral emissions depend on the magnetic field magnitude, either in the equatorial plane, in the acceleration regions, or in the upper atmosphere. Investigating morphological and brightness discrepancies between the two hemispheres provides precious clues on the current systems flowing in the magnetosphere and on the charged particles acceleration mechanisms.

#31

Correcting Galileo's Energetic Particle Detector (EPD) data; Methodology, Implications and Applications

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Abstract

Over the course of its 8 year mission the Energetic Particle Detector, launched in 1989 on the Galileo satellite, took data on the Jovian Particle environment. In the high radiation environment the EPD composition measurement system visibly decayed; higher mass particles, specifically oxygen and sulphur, read far lower energies and count rates at later epochs in the missions. By considering the non-steady accumulation of damage in the detector a correction method has been developed. Applying this correction method allows us to reanalyse the data. Specifically, we obtain new estimations on the surface weathering due to sputtering experienced by Europa and the other icy moons.

#32

Variation of Jupiter's Auroral Electron Parameters Observed by Hisaki/EXCEED

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Abstract

Long-term monitoring of Jupiter's aurora is achieved by the Extreme Ultraviolet (EUV) spectrometer called EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) onboard JAXA's Earth-orbiting planetary space telescope Hisaki until today after its launch in September 2013. The auroral electron energy is estimated using a hydrocarbon color ratio (CR) adopted for the wavelength range of EXCEED, and the emission power in the long wavelength range 138.5–144.8nm is used as an indicator of total emitted power before hydrocarbon absorption and auroral electron energy flux. We investigate the auroral parameters statistically to derive the typical values and their variations from a few hours to several months associated with the Io's volcanic activity.

#33
Variations of Bright Spot emission in Jupiter's Polar Aurora

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Abstract

Jupiter's polar emission is a part of Jupiter's aurora whose behavior is highly unstable with unclear explanation. A bright spot, one of ambiguous features in active region of Jupiter's polar aurora was studied in this work. Jupiter's aurora was observed by the Advanced Camera for Surveys (ACS), an instrument on board the Hubble Space Telescope (HST). The brightness and location variations of bright spots were analyzed. The variation of solar wind propagation at Jupiter obtained from the Michigan Solar Wind Model or MsWim was included in this study as well. Eight bright spots were clearly appeared among all Jupiter's auroral images taken in May 2007. The reappearances of two bright spots in the same day were detected, suggesting occasional occurrence of bright spot. The ionosphere's locations of eight bright spots were found to be varied within 10 degrees. Using Jupiter's magnetosphere-ionosphere mapping based on VIP4, VIPAL, and GAM model, the bright spots' origins in equatorial plane were predicted to be at distances over 70 Jovian radii with local times mostly in the daytime. The bright spots' origins sometimes were mapped to distances beyond 150 Jovian radii or beyond dayside magnetopause. These results are suggested to be related to auroral phenomena in polar cusp and possibly associated with the solar wind. The role of solar wind propagation or other dynamics in bright spot's behavior should be considered in deep detail.

#34
Spatial Distribution and Properties of 0.1 – 100 keV Electrons in Jupiter's Polar Region

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Abstract

In addition to the main emissions in the north and south, Jupiter's ultraviolet (UV) auroral emissions also include satellite-related, polar and other features. Here, we focus on observations from Juno's Jovian Auroral Distributions Experiment (JADE) of 0.1 – 100 keV electrons in Jupiter's polar region, the region poleward of the main emission where the polar emissions are produced. Specifically, we examine the spatial distribution and properties of 0.1 – 100 keV electrons in Jupiter's polar region during Juno's first and subsequent perijoves. Initial results from JADE show a complex environment consisting of mono- and bi-directional field aligned electron beams, regions void of electrons, and regions dominated by penetrating radiation. We present the pitch angle, energy spectra, and energy flux of these electrons and discuss their contribution to producing the polar UV emissions and to the electron environment in Jupiter's polar region.

#35

Wave particle interactions in Jupiter's magnetosphere and associated particle acceleration

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Abstract

Jupiter's magnetosphere is the most powerful planetary particle accelerator in the solar system. To help understand the associated processes, we investigate wave particle interactions, i.e., Landau and cyclotron damping, in Jupiter's magnetosphere for electrons, sulfur, oxygen and hydrogen ions. Therefore we calculate kinetic length and temporal scales, which we cross-compare at various regions within Jupiter's magnetosphere. Based on these scales, we investigate the roles of possible wave particle mechanisms in each region, e.g., Jupiter's plasma sheet, the auroral acceleration region and the polar ionosphere. We thereby consider that the magnetospheric regions are coupled through convective transport, and Alfven and other wave modes. We particularly focus on the role of kinetic Alfven waves in contributing to Jupiter's aurora. Our results will aid the interpretation of particle distribution functions measured by the JEDI instrument onboard the JUNO spacecraft.

#36

Magnetosphere-ionosphere coupling at Jupiter: Expectations for observations on Juno perijove passes based on a steady-state axisymmetric physical model

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Abstract

We evaluate the expected effects of magnetosphere-ionosphere coupling at Jupiter along Juno perijove passes using an axisymmetric physical model. As at Saturn, the model predicts distributed downward field-aligned currents over polar regions mapping to the tail and outer magnetosphere, closed principally through a ring of upward current mapping to the middle magnetosphere, which requires downward acceleration of magnetospheric electrons generating Jupiter's main auroral emission. Auroral location, width, intensity, electron energy, and current density are in accord with values derived from previous ultraviolet imaging, such that the model forms an appropriate baseline for comparison with Juno data. In particular, evaluations of azimuthal field perturbations are derived for anticipated near-planet encounters with middle magnetosphere field lines on individual Juno perijove passes. We comment on model expectations in relation to initial results derived from Juno perijove data.

#37

IPIM: A new numerical Jupiter ionosphere-auroras model

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Abstract

We study the Jovian ionosphere and the auroral energy deposition by developing a new numerical model based on a 16-moment fluid approach initially developed to describe the processes occurring at Earth (Marchaudon and Blelly, 2015). Our model computes the 1D transport of the plasma along interhemispheric magnetic field lines. For each ion (H+, H2+, H3+, He+, HeH+, and CH4+) and for the electrons, the density, the field aligned velocity, the parallel and perpendicular temperature and the field aligned components of the corresponding heat flows are provided. This model allows to derive the temperatures anisotropy in the high latitude regions. In addition, auroral emissions from the H3+ and H2 species are determined. As an input, the neutral atmosphere is taken from the data measured by the Galileo Probe descent (Seiff et al., 1998). The magnetic field is provided by the VIPAL model described in Hess et al., (2011). The precipitating electron fluxes are taken from Gustin et al. (2016). Simulations are run and compared with the available data, and predictions are made for the upcoming JUICE mission (Grasset et al., 2013).

#38

Characteristics of solar wind control on Jovian UV auroral activity obtained from Hisaki EXCEED and ground-based observations

Hajime Kita, Tomoki Kimura, Chihiro Tao, Fuminori Tsuchiya, Hiroaki Misawa, Takeshi Sakanoi, Yasumasa Kasaba, Go Murakami, Kazuo Yoshioka, Atsushi Yamazaki, Ichiro Yoshikawa, Masaki Fujimoto

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Abstract

While the Jovian magnetosphere is known to be dominated by the internal source of plasma and energy, it also has an influence from the solar wind. We made a statistical analysis of the total power variation of Jovian UV aurora obtained by the spectrometer EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) on board the Hisaki satellite. We compared the total UV auroral power in 900-1480 A from 2014 to 2015 with solar wind model. The auroral total power shows a positive correlation to the duration of a quiescent interval of the solar wind before the enhancements of the dynamic pressure. One possible scenario to explain the results is that the magnetospheric plasma content controls the aurora response to the solar wind variation. A long quiescent interval would mean that plasma supplied from Io is more accumulated in the magnetosphere. The solar wind compression of the magnetosphere shifts the plasma inward and cause adiabatic heating to become hot and dense plasma, which leads to an enhancement of the field-aligned current. We also made a coordinated observation with Hisaki and CSHELL on Infrared Telescope Facility when Juno measured upstream solar wind. The intensity of infrared H3+ emission can be used as an index of the atmospheric heating, and the ion wind velocity distribution is related to field-aligned current. In this presentation, we will discuss a possible scenario for the solar wind control of the Jovian aurora including ground-based observations.

#39

The Jovian Energetic Electron Spectrometer (JoEE) on the Particle Environment Package (PEP) for the ESA JUICE mission

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Abstract

The Jovian Energetic Electron (JoEE) sensor is a highly capable compact electron instrument on the Particle Environment Package (PEP) suite for the ESA's JUICE spacecraft. JoEE employs the same electron measurement technique that was used on Cassini/MIMI and Galileo/EPD and provides electron measurements over the energy range from 25 keV to greater than 1.0 MeV. PEP science objectives are to measure charged and neutral particles in the Jupiter magnetospheres and at the moons to understand the magnetospheric and magnetosphere-moon interactions. JoEE, specifically, will take energetic electron measurement and be able to understand source(s) of the energetic electron in the Jovian radiation belt and its energization processes. By measuring large field-of-view (>180) and fine angular resolution (<25), JoEE is able to measure the instantaneous electron pitch-angle distributions and able to discriminate between open and closed Ganymede field lines. Here we describe the measurement requirements and novel measurement techniques that will make significant contribution in the JUICE mission.

#40

Methods for estimation of radiation effects on particle instrument in Jupiter's magnetosphere

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Abstract

Methods for estimation of radiation effects on particle instrument in Jupiter's magnetosphere.

Charged energetic particle radiation is one important environment parameters that need to be considered for every space mission. This type of radiation is always present within our solar system and will be trapped around planets that hosing a magnetosphere. The planet with the strongest magnetic field is Jupiter, this leads to the most intense radiation belt in the solar system. In this environment, the penetrating electrons pose the main problems for spacecraft and payload. The radiation effects includes upset to electronics, accumulated dose degradation, displacement damage to components, background induced noise and deep dielectric charging.

PEP - Particle Environment Package for the JUICE (JUpiter ICy moons Explorer) mission is a plasma package with sensors to characterize the plasma environment in the Jovian system. PEP will measure density and fluxes of positive and negative ions, electrons, exospheric neutral gas, thermal plasma and energetic neutral atoms. This work describes the methods for estimate radiation effects for the PEP payload. Methods includes the use of different 3D radiation tools like sectoring shielding analysis and Monte Carlo simulations (GRAS Geant4). The result from different methods is compared with each other and with existing data from Galileo EPD that was orbiting Jupiter atmosphere in the beginning of the 1990s.

#41

Particle Environment Package (PEP) for the ESA JUICE mission

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Abstract

The PEP suite explores the particle populations in the Jovian system to answer three overarching science questions (1) How does the corotating magnetosphere of Jupiter interact with Ganymede, Callisto, Europa, and Io? (2) How do internal and solar wind drivers cause such energetic, time variable and multi-scale phenomena in the steadily rotating giant magnetosphere of Jupiter? (3) What are the structure and composition of the icy moons exospheres and how do they response to the external conditions?

PEP measures positive and negative ions, electrons, exospheric neutral gas, thermal plasma and energetic neutral atoms (ENA) present in all domains of the Jupiter system over nine decades of energy from < 0.001 eV to > 1 MeV with full angular coverage. PEP includes 6 (six) sensors (1) an ion mass analyzer, (2) an electron spectrometer, (3) a low energy ENA imager, (4) a high energy ENA and energetic ions imager, (5) an energetic electron sensor, and (6) a neutral gas and ions mass spectrometer. For the first time at Jupiter PEP combines global imaging via remote sensing using ENAs with in-situ measurements and performs global imaging of Europa/Io tori and magnetosphere combined with energetic ion measurements. Using low energy ENAs originating from the particle – surface interaction PEP investigate space weathering of the icy moons by precipitation particles. PEP will first-ever directly sample the exospheres of Europa, Ganymede, and Callisto with high mass resolution.

#42

The search for Europa plume signatures in Galileo plasma particle data

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Abstract

Recent observations by the Hubble space telescope hint at recurring water vapour plumes originating from Europa's surface. In-situ sampling of these plumes could allow for the study of Europa's potentially habitable ocean without the need of having to land on it's icy surface.

Lacking in the body of evidence for these plume are indisputable in-situ observations of the plumes. No opportunity to study these plumes in-situ will arise before the early 2030's when ESA's JUICE mission or NASA's Europa Clipper will arrive. However, it may be possible that the Galileo mission, active in the Jupiter system from 1995 to 2003, could have encountered these plumes. In particular it has been suggested that the high plasma densities and anomalous magnetic fields measured during the E12 flyby could be connected to plumes.

In this work we present an overview of in-situ data obtained by the Galileo spacecraft during the Europa flybys it made and compare the data in the context of the search for signs of active plumes. Focus is in particular on the data obtained with the plasma instruments PLS (low energy ions and electrons) and EPD (high energy ions and electrons).

#43

Interaction of the magnetospheric plasma with the Jovian moons for the formation of their atmospheres and ionospheres: NIM / PEP investigations

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Abstract

The Galilean moons are all located well within the Jovian magnetosphere, thus constantly interact with the Jovian plasma. These interactions are mainly governed by conductive sub-surface layers (internally generated magnetic fields), the atmospheric / ionospheric compositions, densities, and mass loading, and the properties of the plasma upstream of the satellites' locations. This interaction not only modifies the local Jovian plasma properties, but also controls the satellites' atmospheres / ionospheres, most noticeably through sputtering (adding material), ionization & pick-up (removing material), and radiolysis. The JUICE / ESA mission to the Jovian system is designed to investigate in detail Jupiter and its Galilean moons. The Neutral Ion Mass Spectrometer (NIM), one of the instruments of the Particle Environment Package (PEP), will conduct direct sampling of the exospheric neutral gas and thermal plasma at Europa, Ganymede, and Callisto, investigating the interaction between the Jovian plasma and these satellites. Special interest is given to Europa's gas release to space and sub-surface release (plumes). In preparation of the JUICE science phase we simulated the interaction by a Monte Carlo model, coupled to a MHD model, which predicts the densities and relative abundances in the exospheres and ionospheres. We show the expected NIM measurements at the three satellites, including local or temporary changes of the atmosphere, e.g., originating from the presence of plumes.

#44

Electron measurements in the low-latitude magnetosphere of Jupiter and in the vicinity of the Galilean moons: Current knowledge and future investigations with the PEP JEI and JoEE sensors onboard the JUICE spacecraft

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Abstract

The Jovian magnetosphere is one of the most fascinating plasma laboratories in space. Driven and powered by the fast rotation of the planet and filled with neutral and charged particles from the internal particle sources, plasma processes evolve on a variety of spatial and temporal scales in the system. In this presentation we will first summarize the results of electron measurements in the Jovian system from previous missions, such as periodicities of electron intensities, transition from bi-directional to trapped electron distributions, relation between electron beams and aurora, injections and interchange transport, radial distribution of energetic electrons. Another target of the electron sensors is to detect photo-electrons possibly generated in the exospheres of the Galilean moons. JUICE/PEP Electron sensors, JEI and JoEE, will go beyond previous missions to provide the long-sought for 3D electron plasma distributions and to reveal the missing link in electron acceleration mechanisms that makes Jupiter the biggest particle accelerator in the solar system. After presenting PEP/JEI and its science goals, we will also discuss how the combined observations with the energetic electron detector PEP/JoEE in the equatorial and mid-latitude magnetosphere as well as during the moon flybys at Europa, Ganymede, and Callisto, will enhance the science output and provide important context for further understanding of past observations with Galileo/EPD.

#45

The Jovian Energetic Neutrals and Ions (JENI) 2nd Generation ENA and Ion Camera of the Particle Environment Package (PEP) on board the JUICE Mission

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Abstract

Following the success of Cassini/INCA and IMAGE/HENA, JENI is the second-generation NASA-funded ENA and Ion camera now being developed for flight on the JUICE Mission. JENI images the Europa gas cloud and magnetospheric injections, and in its ion-mode, captures the energetic particle pressure of H+, O+, and S+.

JENI uses ultrathin foils and TOF with a triple coincidence system for efficient background rejection to achieve measurements of ions in the 0.5 keV - 5 MeV range and ENA imaging in the 0.5 – 300 keV range with 2 degrees resolution. Two foil-covered slits provide a start pulse and position as the primary particle (ion or ENA) enters the sensor. A foil-covered, imaging MCP provides the 2D stop position and timing pulse. Electrons back-scattered from the stop foil are used as a very narrow coincidence timing window with a spatial coincidence. A deflection plate system in front of the aperture slits rejects charged particles up to about 300 keV in its ENA imaging mode.

#46

The Search-Coil Magnetometer onboard ESA JUICE mission

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Abstract

The JUpiter ICy moons Explorer (JUICE) mission is the first large-class (L1) mission in ESA Cosmic Vision. JUICE is planned for launch in 2022 with arrival at Jupiter in 2029 and will spend at least three years making detailed observations of Jupiter's magnetosphere and of three of its largest moons (Ganymede, Callisto and Europa). The Radio and Plasma Wave Investigation (RPWI) consortium will carry the most advanced set of electric and magnetic fields sensors ever flown in Jupiter's magnetosphere, which will allow to characterize the radio emission and plasma wave environment of Jupiter and its icy moons. Here we present the scientific objectives and the technical features of the Search Coil Magnetometer (SCM) of RPWI. SCM will provide for the first time high-quality three-dimensional measurements of magnetic field fluctuations' vector in the frequency range 0.1 Hz – 20 kHz within Jupiter's magnetosphere. High sensitivity (4 fT × Hz-1/2 at 4 kHz) will be assured by combining an optimized (20 cm long) magnetic transducer with a low-noise (4 nV × Hz-1/2) ASICs pre-amplifiers for the front-end electronics. Perturbations by the spacecraft will be strongly reduced by accommodating SCM more than 8m away from the spacecraft on JUICE magnetometer boom. The combination of high sensitivity and high cleanliness of SCM measurements will allow unpreceded studies of waves and turbulence down to electron scales, in particular in key regions such as the magnetopause, the auroral region and the magnetotail current sheet of Ganymede's magnetosphere. This will lead to important advances in understanding plasma transport and particle energization mechanisms in Jupiter's magnetosphere.

#47

Imaging of energetic neutral atoms with the Jovian Neutral Atoms Analyser onboard JUICE: Expectations from charge exchange processes in Ganymede orbit

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Abstract

The JUICE mission will be launched in 2022 and reach Jupiter and the Jovian system 8 years later. The Jovian Neutral Atoms Analyser (JNA) is one of the sensors of the Particle Environment Package (PEP) onboard JUICE. JNA will measure energetic neutral atoms in an energy range from 10eV to 3keV with an angular resolution 11°x7° resolving hydrogen and heavy atoms. One of the main JNA science objectives is to investigate the plasma dynamics in the Ganymede magnetosphere using ENA imaging. Low energy ENAs produced via sputtering and backscattering will be used to image the precipitation regions and, in particular, a boundary of open and closed field lines. ENA produced via charge – exchange between the plasma on the Ganymede magnetosphere and exosphere can be used to obtain the global plasma distribution. For a better understanding of the expected fluxes and the fraction of neutrals from charge exchange processes, we modelled the latter using an existing dataset from [Fatemi et al, Geophys. Res. Lett. 43(10), 2016], the according charge exchange cross sections from [Scherer et al., A & A 563, 2014] and the model of the Ganymede exosphere from [P. Wurz et al., Exo - Climes III , 2014]. We will present the results from our model and the impact of these on JNA testing and calibration.

#48

The Jovian Plasma Dynamics and Composition Analyzer on JUICE

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Abstract

The Jovian plasma Dynamics and Composition analyzer (JDC) is one of six sensors within the Particle Environment Package (PEP) on ESA's JUICE mission to Jupiter. JDC measures 3D distribution functions of positive and negative ions inclusive electrons in the energy range 1 eV per charge to 41 keV per charge. Full hemispherical angular coverage is achieved with 16 radial sectors and scanning electrostatic deflectors. A time-of-flight section is used to determine ion masses simultaneously with high sensitivity but low mass resolution and lower sensitivity but high mass resolution. JDC features of a compact electrostatic analyzer with spherical sectors, start signal generation by surface interaction and a reflectron-type time-of-flight section. The Jovian radiation environment is the main driver for the instrument design. Detailed radiation modelling, shielding design and coincidence schemes for particle detection allow JDC to operate in this challenging environment. We review science objectives of JDC, present the sensor principle and design, its predicted performance in the Jovian environment and compare to most recent laboratory measurements from JDC sensor prototypes.

#49

Feasibility of the exploration of the subsurface structures and ionosphere of Jupiter's icy moons by interferences of Jovian radio waves

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Abstract

A new passive radar technique using interference patterns in the spectrum of the Jovian radio waves has been proposed, and investigated for implementation to JUICE (Jupiter Icy Moons Explorer)/ RPWI (Radio and Plasma Wave Instrument). When there occurs interference among Jovian radio waves directly from Jupiter (W1), those reflected at the ice crust surface (W2), and those reflected at the subsurface reflectors in the ice crust (W3), fine and wide interference patters can be found in the spectrum. Fine patterns are caused by interference between W1 and W2, and between W1 and W3. Wide patterns are caused by interference between W2 and W3. In order to observe these interference patterns, the receiver is required to resolve 100 Hz, and downlink spectra with a frequency range of 2 MHz and resolution of 1 kHz. Based on the calculation of the attenuation rate of the radio waves in the ice from 80 K (surface) to 250 K (at the ice crust bottom), the intensity of the subsurface echo was estimated. Due to extremely high attenuation around the melting temperature, subsurface echoes from depth up to 140 km (just above the ice crust bottom) are expected to be detected. In addition to the subsurface structures, group delay due to ionospheric plasma can be determined by fine interference patterns. When total electron content (TEC) below the spacecraft at an altitude of 500 km is 10^15 /m^2, the frequency intervals of the fine interference becomes 8 % narrower than those expected in vacuum.

#50

JUICE-UVS and Europa-UVS Science Synergies and Juno-UVS Pathfinding

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Abstract

Present and upcoming exploration of the Jupiter system includes Ultraviolet Spectrograph (UVS) investigations all sharing the same basic instrument design. ESA's Jupiter Icy Moons Explorer (JUICE) mission and NASA's Europa Clipper mission are currently both planned to launch in 2022, and their JUICE-UVS and Europa-UVS instruments are in Phase C & Phase B, respectively. These instruments under development are closely related in design to the Juno-UVS instrument, in terms of the modern microchannel plate (MCP) detector technology incorporated and the inclusion of robust shielding from the intense MeV electron radiation environment. These three instruments make up the fourth, fifth, and sixth instruments in a series of successful ultraviolet imaging spectrographs starting with Rosetta-Alice, New Horizons Pluto-Alice, and the Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP). JUICE-UVS and Europa-UVS observe photons in the 55-210 nm wavelength range, slightly expanded relative to Juno-UVS's 70-200 nm. For JUICE-UVS and Europa-UVS, three distinct apertures send light to the off-axis telescope mirror feeding the long-slit spectrograph, while Juno-UVS has a front-end scan mirror to tailor its views of Jupiter's auroral ovals while the spacecraft spins. We further present a comparison of the three UVS investigations by describing the science we plan to address – and synergies, the salient details of the instruments, and the basic concept of operations for each.

#51

Science objectives and implementation of Software-type Wave-Particle Interaction Analyzer (SWPIA) by RPWI for JUICE

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Abstract

Software-type Wave-Particle Interaction Analyzer (SWPIA) will be realized as a software function of Low-Frequency receiver (LF) running on the DPU of RPWI (Radio and Plasma Waves Investigation; PI: J.-E. Wahlund, IRF-Uppsala, Sweden) for the ESA JUICE mission. SWPIA conducts onboard computations of physical quantities indicating the energy exchange between plasma waves and energetic ions. Onboard inter-instruments communications are necessary to realize SWPIA, which will be implemented by efforts of RPWI, PEP (Particle Environment Package; PI: Stas Barabash, IRF-Kiruna, Sweden) and J-MAG (JUICE Magnetometer; PI: M. Dougherty, ICL, UK). By providing the direct evidence of ion energization processes by plasma waves around Jovian satellites, SWPIA contributes scientific output of JUICE as much as possible with keeping its impact on the telemetry data size to a minimum; SWPIA outputs 0.2 kB at the smallest from 440 kB waveform and particle raw data.

#52

The Jovian Energetic Neutral Analyzer for the Particle Environment Package onboard JUICE

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Abstract

Jovian Neutral Analyzer (JNA) is one of six sensors in the Particle Environment Package onboard ESA's JUICE mission to Jovian system. The JNA provides the low-energy (10 eV – 3.3 keV) ENA images originating from the Jovian magnetospheric plasma interaction with the surface/magnetosphere of the Galilean icy moons, and Io torus images through ENA emissions generated from charge-exchange between the co-rotating plasma and the neutral torus. Although the design of the JNA is based on the heritage of CENA instrument onboard Chandrayaan-1 mission to the Moon and the ENA instrument onboard Bepi-Colombo mission to Mercury, a major design update is required to adapt to a very harsh radiation environment in Jupiter. The operation of the JNA combines the techniques of charge conversion surface, electrostatic energy analysis and time-of-flight (TOF) analysis using a start surface and channel electron multipliers (CEMs). Combination of energy and TOF analysis enables mass/charge separation between hydrogen and heavier species such as oxygen and sulfur atoms. Incident direction of ENA is determined by 11 sets of start and stop CEMs which are azimuthally placed around the instrument axis. To suppress background noise due to high energy electrons and gamma rays, the TOF pass length is substantially shrunk compared to the predecessors. We will present the principle and predicted performance of the JNA together with results from prototype tests.

#53

HST observations of variations in Ganymede's oxygen atmosphere and aurora

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Abstract

We analyze the OI] 135.6 nm/OI 130.4 nm intensity ratio at Ganymede from HST/STIS and HST/COS auroral observations and find a range of values that are best explained by a significant difference in the atmospheric compositions of the satellite's leading and trailing hemispheres. The ratio observed on the leading hemisphere is consistently larger than that on the trailing hemisphere. The range of ratios observed implies a trailing hemisphere atomic oxygen column density up to ten times larger than that on the leading hemisphere. We also observe a difference in the response of the aurora of the two hemispheres when Ganymede moves close to the center of the plasma sheet, with an increase in the emission intensity seen on the leading hemisphere and a reduction in the brightness of the trailing hemisphere aurora. This has previously been attributed to an observed shift in the location of the aurora to higher latitudes on the trailing hemisphere and lower latitudes on the leading hemisphere, but a larger Alfvén Mach number due to increased plasma density and a weaker magnetic field at the center of the plasma sheet may also contribute to the effect by reducing the access of electrons to the trailing hemisphere.

#54

Jovian Plasma Interactions with Europa's Exosphere

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Abstract

In anticipation of the arrival of the Europa Clipper mission at its destination, this preliminary work characterizes the interaction of Europa with the Jovian magnetosphere using a multifluid MHD treatment. In order to adequately accomplish this, the system is simulated in multiple relevant configurations, including cases in which Europa is without an exosphere and cases with an exosphere. While not a reflection of reality, simulations of the system without a Europan exosphere—and ionosphere—allow for quantification of the effects of the induced dipole separate from those of plasma sourced at Europa. In the cases in which an exosphere is simulated, asymmetries due to the sputtering derived nature of the exosphere are included. Ionization of exospheric material is calculated dynamically using electron impact ionization, photoionization, and ion charge exchange. Additionally, changes between when Europa is inside of or outside of the Jovian plasma sheet are investigated, as this may cause significant alteration to the Europan ionosphere between Europa Clipper's various flybys.

#55
Multi-fluid MHD modeling of Europa's variable interaction with Jupiter's magnetosphere

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Abstract

The Galileo flybys of Europa and subsequent simulations have established that plasma interactions at Europa depend heavily on Europa's location within Jupiter's rotating magnetosphere, specifically proximity to the plasma sheet and time variation in the ambient magnetic field. Here we simulate the sub-Alfvénic interaction between Europa's ionosphere, exosphere, and induced dipole and Jupiter's magnetosphere with 3D multi-fluid, steady-state, Hall MHD simulations based on BATSRUS. Our plasma interaction model incorporates three ion fluids, an electron fluid, and mass-loading processes to address outstanding questions concerning the interaction between Europa's exosphere and Jupiter's plasma sheet. The ion fluids are O+ and singly ionized molecular Oxygen (O2+) originating in Europa's exosphere, and O+ originating in Jupiter's magnetosphere. The mass-loading processes include photoionization, charge-exchange, recombination, and collisions. They describe the interaction between magnetospheric plasma and Europa's neutral exosphere, and distinguish magnetospheric from exospheric O+. We apply our model to different Galileo flybys and compare model results with magnetic field and plasma observations. We then determine the rate of mass loss from Europa's ionosphere and exosphere to Jupiter's plasma sheet, the magnitude and geographic distribution of Jovian plasma incursion to Europa's surface, and how these features vary with Europa's location in Jupiter's magnetosphere.

#56
Interaction of Europa with Jovian Plasma Torus: Multi-species Hybrid Simulations

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Abstract

We present results of a simulation study of the interaction of Europa with Jupiter's magnetospheric plasma compared to in situ observations of Galileo spacecraft. For simulations we use multi-species three dimensional global hybrid (kinetic ions and fluid electrons) model. The plasma at Europa is composed of pick-up ions which represent an obstacle for the streaming Jovian magnetic field and plasma resulting in the compression of the magnetic field lines which in return causes development of temperature anisotropies. We consider O+ , S++, O++, and S++, as the main constituents of the Jovian plasma torus at Europa while its neutral atmosphere is considered to be composed primarily of (neutral) O2 molecules. We consider ionization processes of the neutral O2 atmosphere which is then a source of dense population of pick-up ions at Europa. We examine global structure of the interaction, formation of Alfvén wings, development of temperature anisotropies and corresponding instabilities, and the fine phenomena caused by the multi-species nature of the plasma. We compare the simulated results with in situ measurements of the Galileo spacecraft.

#57

Plasma interaction at Io: Multi-species hybrid simulations

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Abstract

We present analysis of global 3-dimensional multi-species hybrid simulations of Io's interaction with Jovian magnetospheric plasma. In the multi-species simulations we assume five species, plasma torus is composed of O+, S+ and S++ ions and ions of SO+, SO2+ are created around Io by ionization of its neutral atmosphere. We consider several ionization processes, namely, charge exchange ionization and photoionization/electron impact ionization. We compare our results to data acquired by the Galileo spacecraft. Our results are in a good qualitative agreement with the in situ magnetic field measurements made during Galileo's flybys around Io.

#58

Neutral loss at Europa and Io

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Abstract

Extended neutral clouds are detected along the orbit of Io and Europa. Na, K, S, and O were detected at Io, thanks to spectroscopic observations (Brown, 1974,1981; Trafton 1981; Durrance et al., 1983,1995; Thomas 1996; etc.). The observations at Europa are more indirect: ENA (Mauk et al., 2003), EPD fluxes (Lagg et al., 2003), Lyman-Alpha (Roth et al., 2016). These clouds constitute the main source of plasma for the jovian magnetosphere. As neutral are notoriously difficult to observe (except Na), the composition and the density of these clouds are still uncertain. The processes that lead to neutral escape are diverse: atmospheric and surface sputtering, molecular dissociation, molecular ion recombination, Jeans escape etc. Each process is locally variable and leads to atomic or molecular neutrals escaping at different velocities (i.e. electron impact dissociation leads to very slow atomic neutrals, sputtering might eject faster molecular neutrals). A future modelisation of the formation of these neutral clouds requires the estimation of the escape rate of each process as well as its localization (upstream, downstream, jovian/anti-jovian etc.). We propose to quantify and localize the escape processes from the atmosphere with a coupled MHD/multi-species chemistry model, using a prescribed atmospheric distribution consistent with the observations. We will compare the neutral loss rate at Io and Europa .

#59

Modeling the response of the Io plasma torus to hot electron modulation and volcanic eruptions

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Abstract

The response of the Io plasma torus to superthermal electron modulation and volcanic eruptions is studied using a two-dimensional physical chemistry model (Copper et al., 2016). The model includes radial and azimuthal transport, latitudinally-averaged physical chemistry, and prescribed System III superthermal electron modulation following Steffl et al., [2008]. Volcanic eruptions are modelled as a temporal Gaussian enhancement (e.g., 2x) of the neutral source rate and hot electron fraction (e.g., <1%). However, we adopt an alternative approach for the Steffl et al., [2008] System IV electron modulation. Coupling hot electrons to radial transport, the modulation is determined by the radial flux tube content gradient. Radially-dependent subcorotation is prescribed, consistent with observations [Brown, 1994; Thomas et al., 2001]. We find that the model produces a radially-independent periodicity that is consistent with System IV, which may be directly coupled to subcorotation. We also find that post-eruption, the ionic composition of the torus changes and UV emission rate decreases but in a distinctly different manner for the inner (< 8.5 Rj) and outer (> 8.5 Rj) torus. The pre-eruption-normalized power radiated (ΔPUV) in the inner torus retreats inward while in the outer torus the enhancement transports outward through the boundary. We infer that the recovery is chemically-dominated in the inner torus, and transport-dominated in the outer torus.

#60

Cassini UVIS Observations of Io's Extended Neutral Cloud

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Abstract

Material escaping Io's atmosphere forms an extended cloud, ahead of and behind Io in its orbit around Jupiter. This cloud, primarily composed of neutral oxygen and sulfur atoms, is the source of the majority of plasma in the Io torus. The extended neutral cloud is both faint and difficult to observe, which is why, more than 40 years after the discovery of the Io torus, its spatial extent remains poorly known. Inspired by the exciting new results from JAXA's Hisaki mission (please see presentations by R. Koga and others), I have re-analyzed Cassini UVIS FUV observations made during the Jupiter flyby in late 2000/early 2001. Both neutral oxygen and neutral sulfur have prominent emission lines in the wavelength region covered by the UVIS FUV channel, oxygen at 1304Å and 1356Å and sulfur at 1388Å and 1474Å, all of which are clearly detected. The brightness of the neutral emissions is sharply peaked near Io. Together with observations from Hisaki, these data reveal the spatial extent of Io's extended neutral clouds for the first time.

#61

Response of Jupiter's inner magnetosphere to the solar wind derived from 3-years observation by Hisaki

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Abstract

Because Jupiter's magnetosphere is huge and is rotationally dominated, solar wind influence on its inner part has been thought to be negligible. Meanwhile, dawn-dusk asymmetric features of this region have been reported. Presence of dawn-to-dusk electric field is one of the leading explanations of the asymmetry; however, the physical process of generating such an intense electric field still remains unclear. Using long and continuous monitoring of the extreme ultraviolet emissions from the Io plasma torus (IPT) in Jupiter's inner magnetosphere made by the Hisaki satellite between December 2013 and March 2014, it was revealed that the dusk/dawn brightness ratio of the IPT clearly responses to rapid increase of the solar wind dynamic pressure. The observation indicates that dawn-to-dusk electric field in the inner magnetosphere is enhanced under compressed conditions. Here we present the result of statistical analysis of this feature by using all Hisaki data with IPT monitoring between December 2013 and August 2016. We found clear correlation between the dusk/dawn brightness ratio and solar wind dynamic pressure.

#62

Io in Silhouette: Mapping Io's SO2 atmosphere during Jupiter transit events

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Abstract

The interplay between Io's atmosphere and Jupiter's magnetosphere is a key driver of the plasma environment of the Jovian system. We present a unique analysis of the spatial distribution of Io's SO2 atmosphere using far-UV observations from the Hubble Space Telescope Imaging Spectrograph (STIS). On four occasions, we observed Io as it transited Jupiter, exploiting the planet's bright Lyman-alpha dayglow to measure the absorption of that signal off of Io's limb. Because the photoabsorption cross-section for sulfur dioxide peaks near 122 nm, measurements of the optical depth due to absorption at these wavelengths quantifies the column density of SO2 vapor above the surface. Our results confirm previous observations that the density of SO2 near Io's equator is roughly an order of magnitude higher than that near the poles. In addition to incorporating the STIS point spread function in our models of the Io transit data, we also consider additional attenuation due to atmospheric hydrogen, which is produced by charge exchange reactions between magnetospheric protons and Io's atmosphere. We will present details of our Io transit models, the results, and their implications for the driving source (volcanic vs. sublimation) of SO2 in Io's atmosphere.

#63

Europa's Hydrogen Corona in a Large Set of HST Lyman-Alpha Images

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Abstract

UV spectral images of Europa were obtained by the Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope (HST) on 20 occasions between the years 1999 and 2015. In this study these data are analysed to look for Lyman-alpha emissions from a hydrogen corona. This hydrogen corona was recently discovered in absorption by Roth et al. (2017), also from HST Lyman-alpha images but with Europa in transit of Jupiter. The aim of this study is to confirm the existence of the corona also in emission. We develop a model for the expected emissions from an escaping hydrogen atmosphere and compare it to the data. We furthermore look for systematic variability over time, large scale asymmetries and connections to the local plasma and magnetospheric environment.

#64

On the orbital variability of Ganymede's and Europa's atmospheres

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* LATMOS

Abstract

The atmospheres of Ganymede and Europa atmospheres are produced by radiative interactions with their icy surfaces, sourced by the Sun and Jovian plasma. Sputtered and thermally desorbed molecules are tracked in our Exospheric Global Model (EGM), a 3-D parallelized collisional model. This code was developed to reconstruct the formation of the upper atmosphere/exosphere of planetary bodies interacting with the solar photon flux and the magnetospheric plasma. Here, we describe the spatial distribution of the H2O and O2 atmospheres, and their variability with the satellite rotation around Jupiter. In particular, we show that the O2 atmosphere is characterized by timescales of the order of the rotational period. Jupiter's gravity is a significant driver of the spatial distribution of the heaviest exospheric components. Both sourcing and Jovian gravity are needed to explain the observed auroral emissions at Ganymede, as well as the persistent dawn/dusk asymmetry in the Europa exosphere.

#65

Ganymede's atomic hydrogen atmosphere and surface reflectivity in HST/STIS Lyman-α images

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Abstract

An extensive number of far-ultraviolet observations of Ganymede's auroral and atmospheric emissions were obtained by the Space Telescope Imaging Spectrograph (STIS) of the Hubble Space Telescope (HST) from 1998-2014. The images were obtained when Ganymede was located at different orbital phase, providing information about both the trailing and leading hemispheres. We analyze the hydrogen Lyman-α (1216 Å) signal and model the different contributing sources. The comparison between the images and the model provides information about the temporal and hemispherical variability of atomic hydrogen in Ganymede's atmosphere. Additionally, the images allow us to study the reflectivity of the moon's surface at Lyman-α, which appears to be anti-correlated with images at visible wavelengths.

#66

3D Hall MHD-EPIC Simulations of Ganymede's magnetosphere

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Abstract

Fully kinetic model of a complete 3D magnetosphere is still computationally expensive and not feasible considering present capability of processors while magnetohydrodynamic (MHD) model has been successfully applied in a wide range of plasma simulation. We have recently developed a new modeling tool to embed the implicit particle-in-cell (PIC) model iPIC3D into the Block-Adaptive-Tree-Solarwind-Roe-Upwind-Scheme magnetohydrodynamic (MHD) model. This results in a global kinetic model of a complete magnetosphere, and the model is now able to use stretched spherical coordinates with adaptive mesh refinement (AMR) in key regions of the magnetosphere and adopts a semi-implicit scheme for solving the magnetic induction equation using large time steps. We have applied the model to Ganymede, the only moon in the solar system known to possess a strong intrinsic magnetic field, and included finite resistivity beneath the moon's surface to model the electrical properties of the interior in a self-consistent manner. The kinetic effects of electrons and hot ions on the dayside magnetopause and tail current sheet are captured with iPIC3D. Our simulation provides better understanding of the global magnetospheric structure as well as the flux transfer events and magnetic reconnection under sub-Alfvènic plasma conditions

#67

Callisto plasma interactions - now with an ionosphere

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Abstract

We use a hybrid model to study the plasma interaction between the Jovian magnetosphere and the Galilean moon, Callisto. Situated far from Jupiter, Callisto is experiencing a highly variable external magnetic field, resulting in the highest relative inductive response of the Galilean moons. Callisto has an atmosphere of mainly carbon dioxide, which when ionised by photons or electron impacts will be picked up by the convective electric field of the Jovian magnetosphere. With the neutral atmosphere represented by macroparticles, we are not limited by the resolution of the simulation cell size, and can resolve the scale height of Callisto's atmosphere. We investigate the importance of asymmetric neutral sublimation while varying the direction of the Sun with respect to the magnetospheric plasma flow. This could answer what conditions have to be met for a global/local ionosphere to exist.

#68

Plasma Interaction and Energetic Particle Dynamics near Callisto: A Case Study of the Galileo C10, C21, and C23 Flybys

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Abstract

Callisto's magnetic environment is characterized by a complex admixture of induction signals from its conducting subsurface ocean, the interaction of corotating Jovian magnetospheric plasma with the moon's ionosphere and induced dipole, and the non-linear coupling between the effects. In contrast to other Galilean moons, ion gyroradii near Callisto are comparable to its size, requiring a kinetic treatment of the interaction region near the moon. Thus, we apply the hybrid simulation code AIKEF to constrain the competing effects of plasma interaction and induction. We determine their influence on the magnetic field signatures measured by Galileo during the C10, C21, and C23 Callisto flybys. We use the magnetic field calculated by the model to investigate energetic particle dynamics and their effect on Callisto's environment. From this, we provide a map of global energetic particle precipitation onto Callisto's surface, which may contribute to the generation of its atmosphere.