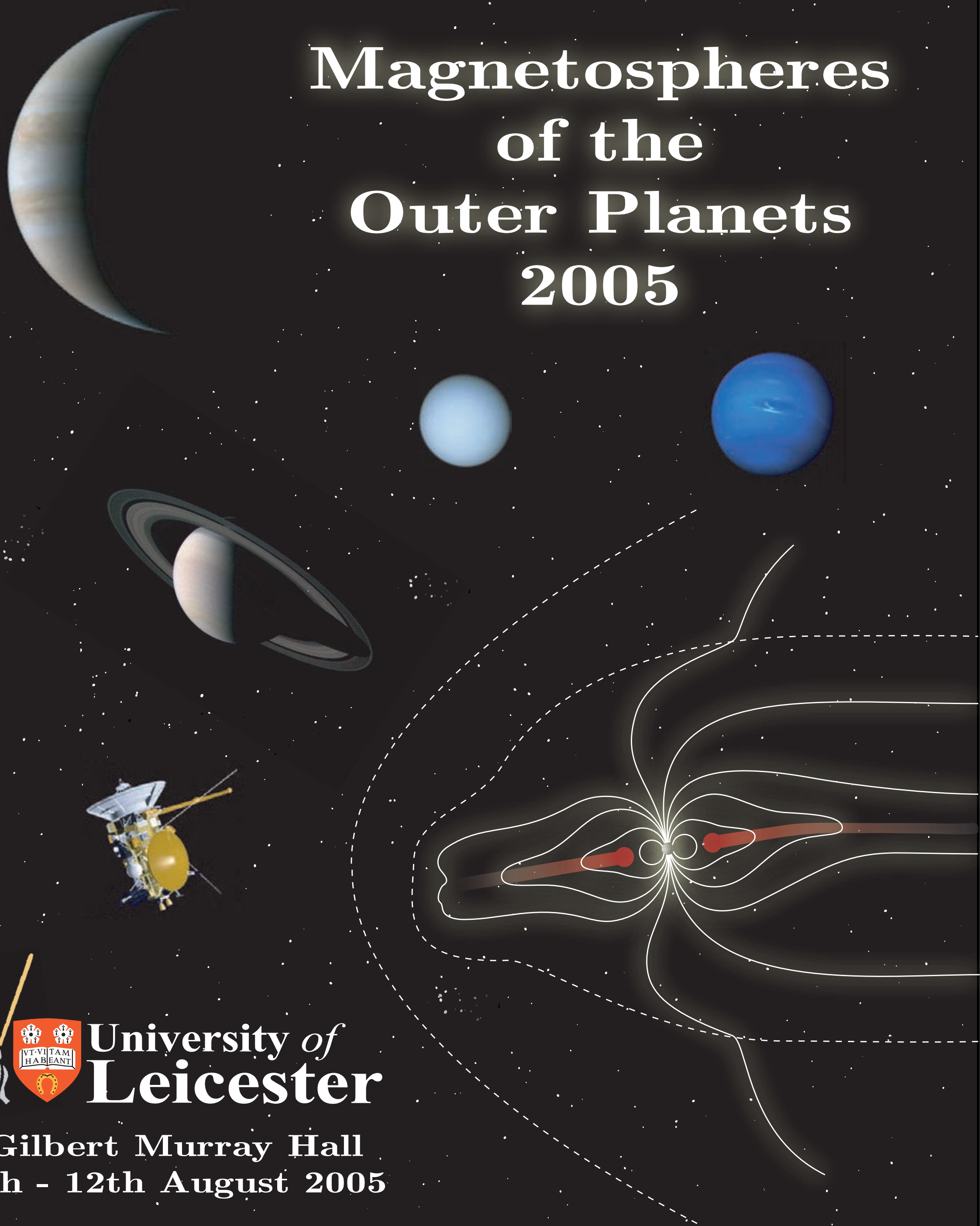
Magnetospheres of the Outer Planets 2005



University *of* Leicester

Gilbert Murray Hall
7th - 12th August 2005

MAGNETOSPHERES OF THE OUTER PLANETS 2005

7th – 12th August 2005

Gilbert Murray Hall of Residence
University of Leicester
UK

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MOP 2005 Programme

Monday 8th August 2005: Jupiter

Time	Author	Title	Page No.
08:30-08:40	**LOC**	**Welcome and practical information**	
Chairman	*M. Kivelson*		
08:40-09:10	**Southwood**	**Future planetary science activities in Europe**	
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09:40-10:10	**Clarke**	**The morphology of Jupiter's aurora**	13
10:10-10:25	Gladstone	The centre-to-limb behaviour of Jupiter's Lyman-alpha emissions	14
10:25-11:00	**Break**		
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13:45-14:00	Fukazawa (by Walker)	The influence of IMF B_y on the structure and dynamics of the jovian magnetosphere	21
14:00-14:15	Tao	Magnetic field fluctuations in the jovian magnetotail induced by solar wind dynamic pressure	22
14:15-14:30	Nichols	Magnetopause reconnection rates at Jupiter: Inferences based on IMF and solar wind plasma observations at ~5AU	23
14:30-14:45	Anagnostopoulos	A series of ~10 hour quasi-periodic energetic ion bursts observed by ACE and Ulysses: Evidence of unusual jovian ion emissions during a disturbed heliosphere?	24
14:45-16:00	**Break and Jupiter poster viewing**		
Chairman	*E. Bunce*		
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16:15-16:30	Bolton	Jupiter's radiation belts	26
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16:45-17:00	Cecconi	Direction finding study of the jovian quasi-periodic bursts with the Cassini/RPWS/HFR radio receiver	28
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Tuesday 9th August 2005: Jupiter

END

Jupiter Posters

Wednesday 10th August 2005: Saturn

Thursday 11th August 2005: Saturn

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08:30-08:45	**Preliminary discussion on location of next MOP meeting. Vote Friday 10:30**		
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13:30-14:30	**Saturn poster viewing**		
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END			

Friday 12th August 2005: Saturn and Comparative Magnetospheres

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Chairman	*F. Crary*		
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Chairman	*N. Achilleos*		
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14:00-14:15	Russell (by Bertucci)	Mass loading, fast neutral production and ion cyclotron waves in the magnetospheres of Jupiter and Saturn	118
14:15-14:30	Hamilton	Observations of Saturn's ring current and comparisons with Earth and Jupiter	119
14:30-14:45	André	Local stability criterion for quasi-interchange modes in giant planet magnetospheres	120
14:45-16:00	**Break and Saturn poster viewing**		
Chairman	*T. Hill*		
16:00	**Open discussion**		
-	**LOC**	**Closing remarks**	

MEETING CLOSE

Saturn and Comparative Magnetospheres Posters

JUPITER

♃

Oral Presentations

Monday and Tuesday

-**INVITED-**

Jupiter's Magnetic Field: Through a Glass Darkly

J. E. P. Connerney(1), T. Satoh(2), J. T. Clarke(3)
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(2) Kumamoto Univ., Japan
(3) Boston Univ., MA

Remote observations of the Io Flux Tube (IFT) footprint obtained using NASA's Infrared Telescope Facility (IRTF) on Mauna Kea and the Hubble Space Telescope (HST) have been used to determine the coefficients of a spherical harmonic model of the Jovian field. Unlike the VIP4 model, which used IFT observations to constrain a model largely determined by in-situ observations, this model is based on the IFT observations and uses just a touch of Voyager 1 magnetic field data to fix the magnitude of the field. The IFT observations determine the geometry of the field but do not by themselves constrain the magnitude of the field. The result is an interesting model, described here, that fits remote observations very well and avoids the potential ill effects of inconsistent in-situ datasets.

-INVITED-

The Morphology of Jupiter's Aurora

John T. Clarke
Boston University

A large number of observations of Jupiter, spanning more than 25 years and a wide range of wavelengths, has resulted in a coherent picture of the distribution of auroral emissions. Auroral processes at Jupiter are generally divided into three independent regions: the satellite footprints, the main oval, and the polar emissions. The origin of the satellite footprint emissions at Io, Europa, and Ganymede is well known, although the detailed physical processes which govern these emissions are not yet understood. The main oval emissions are generally believed to be driven by processes at ~ 20-30 Jovian radii, the distance where outward drifting plasma falls behind corotation driving currents in and out of the planet's ionosphere. The origin of the polar emissions is less well understood, although some of the morphological characteristics suggest a mapping to general regions of Jupiter's magnetosphere. In addition, auroral storms have been observed in three different regions of the auroral zones north and south. The dawn storms appear to map to the dawn side middle magnetosphere, polar flares may map to a region close to the magnetopause boundary, and polar arcs observed near local midnight might map to regions of reconnection in the magnetotail region. These and other current ideas about Jupiter's auroral morphology will be presented in this talk.

The Centre-to-Limb Behaviour of Jupiter's Lyman-alpha Emissions

G. Randall Gladstone(1) and John T. Clarke (2)
(1) SWRI
(2) Boston University

HST-STIS long-slit echelle spectra of Jupiter's Lyman-alpha emissions show a marked increase in line width on approaching the limb of the planet. This suggests that the broad wings seen in previous observations of Jovian auroral Lyman-alpha line profiles may be due instead to resonant scattering of the solar Lyman-alpha line. We examine this idea using carefully reduced STIS spectra and a resonance line radiative transfer code which includes a more accurate representation of the incident solar line profile (consistent with a series of measurements by SOHO-SUMER). Detailed simulations of the centre-to-limb behaviour of Jupiter's Lyman-alpha line profile will be presented.

-**INVITED-**

Implications of Jovian X-Ray Emission for Magnetosphere-Ionosphere Coupling

T. E. Cravens(1), J. H. Waite, Jr.(2), R. F. Elsner(3), A. Bhardwaj(3), G. R. Gladstone(4), G. Branduardi-Raymont(5), and V. Kharchenko(6)
(1) University of Kansas
(2)University of Michigan
(3) NASA Marshall Space Flight
(4) Southwest Research Institute
(5) Mullard Space Science Laboratory,University College London
(6) Harvard-Smithsonian Center for Astrophysics

X-ray observations of Jupiter made by the Chandra X-Ray Observatory (CXO) have revealed a powerful x-ray aurora located in the polar caps. We have previously suggested that auroral x-rays result from energetic heavy ion precipitation, either on open field lines connecting to the solar wind or on closed field lines reaching to the outer magnetosphere. The auroral x-ray spectra measured by the CXO ACIS-S instrument exhibit emission lines associated with high charge-state oxygen ions (O7+ and O6+) and maybe with high charge-state sulphur ions (S8+, S9+, S10+). Such emission could be produced by the precipitation of ions with energies in excess of 8 MeV, but sufficient particle fluxes do not exist in the outer magnetosphere. However, field-aligned electric fields could accelerate the ambient ions to the necessary energies. On the other hand, oxygen and carbon lines are present in a published x-ray spectrum of Jupiter's aurora from the XMM Newton satellite, but sulphur lines are either weak or absent. Perhaps for this case, solar wind ions precipitating on open field lines are responsible for the emission. In this paper, we will present model calculations of the precipitation process for both the solar wind and the magnetospheric ion precipitation scenarios. Significant downward field-aligned electrical currents carried both by the precipitation ions and by upwardly accelerated secondary electrons appear in the scenarios. Bunce and Cowley have suggested that such currents could be caused by sporadic reconnection at the dayside magnetopause.

Search for Rotational H_3^+ Emission in Jupiter's Aurora

L. M. Trafton(1), S. Miller(2), J. Lacy(3), T. K. Greathouse(4)
(1) U. Texas at Austin
(2) UCL
(3) U. Texas at Austin
(4) LPI

Auroral processes on Jupiter are known to contribute to pronounced near-IR emission from hot H_2 and H_3^+ along northern and southern arcs associated with maintaining the co-rotation of the magnetosphere. Aurorae have been observed for the FUV electronic and near-IR fundamental bands of H_2, and for the fundamental and first overtone bands of H_3^+. Also, two hot lines of vibrationally excited Jovian H_3^+ were recently reported by Raynaud et al. (2004). All of these H_3^+ emission lines originate from ions in the first or second vibrational state, except that the hot lines result from the v=3->2 transition. To investigate the energy input and local heating of Jupiter's ionosphere by aurora, we obtained mid-IR observations of Jupiter in 2002 using the crossed-dispersed etalon TEXES at the IRTF with R=70,000 in search of emission from the pure rotational lines of H_3^+. These originate from the populous rotational levels of the ground vibrational state and should represent the thermal emission. The wavelengths are based on theoretical calculations using energy levels rather than on laboratory spectra of these lines. No clear detection resulted but the search was complicated by the rich spectrum of hydrocarbon emission lines that pervade Jupiter's mid-IR spectrum. We present the results of our survey.

The Role of Reconnection in Driving Plasma Convection in Jupiter's Magnetosphere

K. K. Khurana, H. K. Schwarzl
Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA, 90095, USA

There is clear evidence in the magnetic field observations from the Galileo spacecraft that in addition to the strong rotational control by Jupiter's ionosphere on the Jovian plasma, the solar wind also considerably influences the structure and dynamics of Jupiter's magnetosphere. These observations show that a partial ring current and an associated Region-2 type field-aligned current system exist in the magnetosphere of Jupiter. It is well known that in the Earth's magnetosphere such structures are created by the asymmetries imposed by the solar wind driven convection.

Many other in-situ and remote observations also point to dawn-dusk asymmetries imposed by the solar wind. For example, new observations from the Energetic Particle Detector show that the plasma is close to corotational on the dawn side but lags behind corotation in the dusk sector. Field and plasma observations also show that the Jovian current sheet is remarkably different in its character in the dawn and dusk sides. The current sheet is thin and highly organized on the dawn side but thick and disturbed on the dusk side.

To explain these observations, we invoke both an internally driven convection (that transports plasma from Io's torus) and an externally driven transport maintained by reconnection. We postulate that reconnection on the nightside is an important feature of Jupiter's magnetosphere but suggest that the neutral line is slanted, being much closer to Jupiter on the dawnside. We discuss how the internal and external drivers together set up a convection system and transport plasma and magnetic flux in Jupiter's magnetosphere. We explore the consequences of this convection system on the flows, current sheet and the Jovian aurorae.

Alfvén Travel Time in the Jovian Magnetosphere

Fran Bagenal, Laurel Rachmeler
University of Colorado, Boulder

Measurements indicate that the magnetospheric plasma flow is dominated by rotation which tells us that the magnetosphere is strongly coupled to the planet. Rotation confines the plasma towards the equator, the bulk motion is predominately rotational (albeit lagging behind rigid corotation) and Jupiter's flywheel is the main source of energy. The low plasma density away from the equator, however, means that it is difficult for currents to couple the equatorial plasma to the planet's polar regions. Furthermore, high densities and low magnetic fields in the plasma sheet result in low Alfven speeds and long travel times for Alfven waves between equator and the ionosphere. At larger distances from the planet, particularly on the dusk/night side, the time scale for Alfven waves to couple the plasma sheet to the jovian flywheel becomes larger than time scale for outward expansion and the plasma becomes decoupled. In this paper we develop an empirical model of the Alfven velocity in the magnetosphere of Jupiter and estimate the Alfven travel time between the equator and ionosphere as functions of local time and radial distance.

Dynamical Consequences of Two Modes of Centrifugal Instability in Jupiter's Outer Magnetosphere

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(2) Institute of Geophysics and Planetary Physics and Department of Earth and Space Sciences, UCLA, Los Angeles, CA 90095-1567, USA

We put forward a study referenced to data, particularly, magnetic data from the seven spacecraft that have visited the jovian system. Our thesis is that many global scale properties of the middle and outer portions of the Jovian magnetosphere can be interpreted in terms of plasma there experiencing either marginal or explosive centrifugal instability. The night-side explosively unstable sector leads to an outflow of material down tail that thins the plasma disk. The outflow evacuates portions of the flux tubes, causing the outer portions to break off and to leave depleted closed flux tubes behind. This outflow almost certainly always dominates any solar wind-controlled reconnection in the magnetotail. As the residual closed depleted flux tubes move onto the dayside at large radial distance on the morning side at high speed, they form a distinct low density plasma/magnetic regime that overlays a thin plasma disk. Here the instability is marginal at the outer edge of the sheet. This marginality results in weak loss of plasma from its outer edge during rotation for which there is evidence. The solar wind imposed geometry causes the plasma disk to thicken as flux tubes rotate from dawn to noon but even at noon there appears to remain a depleted region. On the afternoon side, we will describe a heating process that pushes the tubes well above marginal instability. The plasma disk thickens substantially as it moves from noon to dusk and assimilates the previously empty flux tubes of the outer magnetosphere. It is probable that this assimilation is accomplished by the instability on a short perpendicular scale leading to Bohm diffusion of plasma to refill the previously emptied tubes. The model explains the well-known dawn-dusk asymmetry in the UV aurora as being due to the vastly larger tapping of the ionospheric flywheel in the afternoon sector to drive the magnetospheric heating and instability that the model proposes.

Stress Balance in Thin Current Sheets: Implications for Pressure Anisotropy in the Jovian Magnetosphere

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The thickness of the observed currents sheet in the middle magnetosphere and the magnetotail of Jupiter is inferred to be small in comparison to radial distance times ratio of normal to tangential magnetic field. The radial pressure gradient is then too small to balance the magnetic tension of the current sheet, and stress balance requires either acceleration (e.g. corotational motion) or pressure anisotropy. The magnetic tension integrated across the thickness of the current sheet, however, can be balanced by an excess of parallel pressure only when that pressure exists in the lobes outside the current sheet. It is generally assumed that plasma stresses in the lobes are negligible, which implies that the integrated tension must be balanced by acceleration alone. Pressure anisotropy can then play a role only locally, within the interior of the current sheet. From stress balance equations in tangential and normal directions I show that the pressure anisotropy depends on the relative variation of mass content and tangential magnetic field with distance from the of the current sheet. Specifically, the difference of parallel and perpendicular pressure normalized to twice the magnetic pressure (the quantity that is equal to 1 for the so-called firehose condition) is equal to 1 minus the ratio

(fraction of mass per unit area)/(fraction of field reversal).

The anisotropy approaches zero at the edges of the current sheet. At the centre, the parallel pressure is the larger one if the mass density is depressed relative to the average, the perpendicular pressure is larger if the mass density is enhanced.

The Influence of IMF By on the Structure and Dynamics of the Jovian Magnetosphere

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The interplanetary magnetic field (IMF) at Jupiter's orbital distance is mostly in the Y-JSE (Jupiter Solar Ecliptic) direction. We have used a global magnetohydrodynamic simulation of the interaction of the solar wind with Jupiter's magnetosphere to investigate the effects of IMF By on the magnetospheric configuration and dynamics. The simulation was run for 50 hours with IMF By= 0.42nT, IMF entirely in the Y-direction and then the IMF was rotated to have a northward component of Bz= 0.42nT and By=0.42nT. Following the inclusion of the northward IMF a neutral line formed in Jupiter's magnetotail at X=-70R_J. This was associated with a complex flux rope like structure. This structure remained fixed in the magnetotail in contrast with the case when the IMF was purely northward and periodic plasmoids were launched tailward.

Magnetic Field Fluctuations in the Jovian Magnetotail Induced by Solar Wind Dynamic Pressure Enhancements

Chihiro Tao (1), Ryuho Kataoka (2), Hiroshi Fukunishi (1), Yukihiro Takahashi (1), and Takaaki Yokoyama (3)
(1) Tohoku University
(2) National Institute of Information and Communications Technology
(3) University of Tokyo

We investigate magnetic field fluctuations observed by the Galileo spacecraft located inside Jovian magnetosphere. Our aim is to understand the response of the Jovian magnetosphere to the large enhancements of solar wind dynamic pressure. The lack of solar wind monitoring just upstream of the Jovian magnetosphere renders such analysis problematic. In order to overcome this problem we have performed a one-dimensional magnetohydrodynamic (MHD) propagation of the solar wind parameters measured upstream near the Earth. Solar wind data obtained from the IMP-8, WIND, and ACE spacecraft in the vicinity of the Earth are used as input parameters for solar wind simulation. Verification of the simulated solar wind parameters is performed by comparing them with actual values obtained by the Ulysses spacecraft in the vicinity of the Jovian orbit. The estimated arrival error of dynamic pressure enhancement events is found to be <2 days if the acute angle of Jupiter-Sun-Earth is <50º. We select 9 events that meet our criterion of event selection, i.e., an increase of solar wind dynamic pressure of >0.25 nPa at the Jovian orbit. Characteristic changes in the magnetic field fluctuations were found for all of the 9 events. For 8 of the 9 events, a rectangular waveform with the Jovian rotation period of 10 hours disappears in response to the arrival of large dynamic pressure enhancements. Furthermore, it is found that the amplitude of magnetic field perturbations in the ultra-low frequency (ULF) (0.3 - 10 mHz) increases during the disappearance of the rectangular waveform, in proportion to the maximum amplitude of solar wind dynamic pressure enhancements.

Magnetopause Reconnection Rates at Jupiter: Inferences Based on IMF and Solar Wind Plasma Observations at ~5AU

J.D. Nichols and S.W.H. Cowley
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We examine data from the Ulysses VHM/FGM and SWOOPS instruments obtained during periods when the spacecraft was located near 5AU and within 5 degrees of heliocentric ecliptic latitude from Jupiter's orbit (December 1991 to May 1992, February to September 1998, and March to September 2004), along with data from the Cassini MAG and CAPS instruments obtained during the Jupiter flyby in 2000/2001. These periods represent different phases in the solar cycle, such that the conditions in the solar wind are observed to vary accordingly. We estimate the jovian magnetopause reconnection voltages using the Jackman et al. (2004) Saturn algorithm adapted to Jupiter, and examine how this varies over the course of the solar cycle. In addition, we consider the effect of the relative orientation of the spin vectors of Jupiter and the Sun. As Jupiter orbits the Sun the 'clock angle' of the jovian spin axis in RTN coordinates varies with orbital longitude over a range of +/- ~7.5 degrees, while the offset of the magnetic dipole axis contributes an additional variation of +/- ~9.5 degrees every jovian day. We show that this results in the IMF sector with positive clock angle being favoured for reconnection when the jovian spin axis clock angle is also positive, and vice versa. Overall, therefore, we present a picture of how the reconnection-mediated solar wind-Jupiter interaction varies over a wide range of conditions.

A Series of ~10 Hour Quasi-Periodic Energetic Ion Bursts Observed by ACE and Ulysses on Days 25-27, November 2003: Evidence of Unusual Jovian Ion Emissions During a Disturbed Heliosphere?

Anagnostopoulos G., I. Louri, P. Marhavilas P. and E. Sarris
Space Research Laboratory, Demokritos University of Thrace, Xanthi, Greece

A series of short (~1-3 hours) duration ~10 / 5 quasi-periodic ion flux enhancements above the background level of a solar particle event was observed by ACE and Ulysses on days 25-27, November 2003. The series of ion enhancements were more pronounced at the position of ACE than at Ulysses. At those times, ACE was near the Sun –Earth line, at a distance of ~240 R_E from Earth and near IMF lines connecting Jupiter with Sun while Ulysses moved from north heliolatitudes toward the ecliptic plane and Jupiter (~5.25 AU from Sun, ~2000 RJ from the planet). At ACE, the ion events were observed during times of ~10/5 hour quasi-periodic IMF directional variations, with onset / decay phases showing cross-field anisotropies suggesting the quasi-periodic approach / removal of a rather large scale particle layer probably remaining "near" ACE for almost 2.5 days. During the main phase of events the PADs suggest field aligned flows from the anti-sunward direction. The spectral, compositional and other particle characteristics of the unusual ~10 / 5 quasi-periodic ion flows observed both "near" Earth and Jupiter are examined and various (planetary / interplanetary) sources are considered; a Jovian origin of these ~10 / 5 hour quasi-periodic ion bursts is also discussed.

GMRT Observation of Jupiter's Radio Emission

Anil Bhardwaj (1,*), C.H. Ishwara-Chandra (2), N. Udaya Shankar (3), Ronald F. Elsner (1), G. Randall Gladstone (4), Girish K. Beeharry (5)
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(2) National Centre for Radio Astronomy, TIFR, Pune Univ. Campus, Pune, India.
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(4) Southwest Research Institute, San Antonio, P.O. Drawer 28510, TX 78228, USA.
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The decimeteric radio emissions from Jupiter are dominated by synchrotron emissions originating from high-energy electrons trapped in Jupiter's inner radiation belts at 1.3-4 Jovian radii. We have observed Jupiter during February 24 - March 3, 2003 with GMRT to study its radio emissions in the dual frequency linear polarization mode at 610 and 240 MHz simultaneously. Each day's observations lasted for about 10 hours (the rotation period of Jupiter), the time period span ~1800-0400 IST (1230-2230 UT). The primary calibrator was taken as 3C147 and phase calibrator source used was 1021+219. We used a bandwidth of 6 MHz for observations with 64 frequency channels covering a span of 8 MHz. The visibilities were recorded with an integration time of 16 seconds. We will present results of these GMRT observations of Jupiter's radio emissions, which were taken in conjunction with observations in X-rays from Chandra X-ray Observatory and in ultraviolet from Hubble Space Telescope. An unusual correlation is observed between the Jupiter radio flux and the solar radio flux at 10.7 cm, which will be discussed.

Jupiter's radiation belts

S. J. Bolton (1), M. Klein (2), S. Levin (2), R. Thorne (3), D. Santos-Costa (1)
(1) Southwest Research Institute
(2) JPL
(3) UCLA

The radiation belts of Jupiter were serendipitously discovered after the detection of bursts of jovian radio emission in the decametric wavelength band by Burke and Franklin in 1955. Following the decametric detection, radio observations of Jupiter became more frequent, and by 1958 observations at a few centimeters measured a black body disk temperature of approximately 150 K, indicative of the temperature of Jupiter's atmosphere near 1 bar. Since their discovery, the inner (<5 RJ) jovian radiation belts have been routinely monitored by radio telescopes measuring the synchrotron emission emanating from the relativistic electrons trapped close to Jupiter. These observations combined with the relatively few in-situ measurements obtained by spacecraft traversing close to Jupiter have provided a general understanding of Jupiter's inner radiation belts and their variability. In this talk, a review of Jupiter's radiation belts will be presented with an emphasis on the synchrotron emission observations both past and present.

Observations of Short Term Variations of Jovian Synchrotron Radiation at 325 MHz

F. Tsuchiya(1), H. Misawa(1), T. Watanabe(1), S. Nomura(1), K. Imai(1), A. Morioka(1), Y. Miyoshi(2), T. Kondo(3)
(1) Tohoku University
(2) Nagoya University
(3) National Institute of Information and Communications Technology

Iitate Planetary Radio Telescope (IPRT) which measures meter to decimeter radio waves has been developed at the Iitate observatory of Tohoku University in order to enable continuous monitoring of Jovian synchrotron radiation (JSR) in the low frequency range. IPRT is a fully steerable offset parabola antenna whose physical aperture area of 1023 square-meters. The front-end receivers and beam formed dipole feed system for 325 MHz are now set up and the noise temperature of the receiver system and the aperture efficiency of the telescope achieved 80K and 65%, respectively. The receiver system also has a function of gain calibration, which enables absolute measurement of weak radio sources and their time variations with accuracy.

Primary purpose of IPRT is continuous observation of JSR and research of the dynamics in the Jovian inner magnetosphere by detecting short-term variations of JSR with the time scale of a few days to a month. The monitoring observation of JSR has been started from Oct., 2003. After a correction of the receiver gain and the noise level and elimination of background galactic component behind Jupiter, we derived absolute flux of JSR. It is found that the flux density of JSR at 325 MHz shows short term variation during both strong and quiet solar conditions. During an unusual active solar event occurred at Oct. 28 and 29 in 2003, the flux of JSR showed unusual increase of its magnitude by 50 %, which may be due to an unusual response of Jupiter's radiation belt associated with the rarely strong solar event.

Direction Finding study of the jovian Quasi-Periodic Bursts with the Cassini/RPWS/HFR radio reciever.

B. Cecconi (1), P. Zarka (2), M. Kivelson (3), R. Prangé (2), L. Pallier (2), F. Bagenal (4), W. S. Kurth (1), G. B. Hospodarsky (1)
(1) Dept. of Physics & Astronomy, The University of Iowa, Iowa City, Iowa, USA
(2) LESIA, Observatoire de Paris, Meudon, France
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The jovian Cassini flyby provided a unique opportunity to try to understand the origin of the Quasi-periodic (QP) Bursts. The QP bursts are the least understood jovian radio emission. They show temporal variabilities on several time scales (from a few minutes to the jovian sidereal period). The QP bursts also show a very broad emission solid angle. Furthermore, as their origin and emission process are still unknown, the direction finding capabilities of the Cassini/RPWS/HFR instrument gave us the opportunity to retrieve the QP bursts source location and try to understand the physics involved in these emissions. Given earlier reports of correlations between QP bursts and energetic particles and the apparent importance of ~40-minute periodicities in both the QP bursts and other phenomena in the magnetosphere, understanding the source and generation of these radio bursts is key to understanding a number of aspects of Jupiter's magnetosphere and its processes.

Modelling Thermosphere-Magnetosphere Coupling at Jupiter

C G A Smith, S Miller & A D Aylward
Atmospheric Physics Laboratory, University College, London

We present a simple model of the coupling between the thermosphere and magnetosphere of Jupiter. The thermospheric component is derived from the Saturn Thermosphere-Ionosphere Model (Mueller-Wodarg et al., 2005). The magnetosphere and height integrated ionospheric conductivities are based on a modified version of the Nichols & Cowley (2004) model of the Jovian middle magnetosphere.

The model provides insight into the probable distribution of Joule heating in the thermosphere, and the effects of ion drag on the dynamics and energy redistribution. We are also able to quantify the latitudinal variation of the 'slippage' factor k, and the effects of increased Joule heating associated with possible electric field fluctuations.

-**INVITED-**

Moon-Magnetosphere Interactions

Margaret Galland Kivelson
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The interaction of the flowing plasma of a planetary magnetosphere with a body in orbit around the planet depends on characteristics of the central body (size relative to the characteristic gyroradii of the ambient plasma, ratio of the surface magnetic field to the field of the ambient plasma, stability and direction of the internal magnetic field, rate of neutral sputtering from the surface and/or atmosphere, presence of a conducting ionosphere) and of the magnetospheric plasma (the ratio of the plasma pressure to the magnetic pressure, the Mach number of the flow relative to the body). Starting in the 1960s with the first hint that there was a link between Io's orbital location and radiation from the Jovian ionosphere, the diverse interplay among these aspects of the interaction has been ever more fully documented first for the Galilean moons of Jupiter and in the past months for some of Saturn's moons. This talk will seek to identify recent observations of importance to our understanding of the moon-magnetosphere systems and interesting questions still to be answered regarding the interactions.

-**INVITED-**

Progress in Understanding Longitudinal Structures in the Io Torus

Nicholas M. Schneider
LASP, University of Colorado

Shortly after the discovery of the Io plasma torus in 1976, observers detected strong variability at Jupiter's rotational period. At first it appeared that the torus was simply longitudinally asymmetric, and that the torus brightened when denser regions rotated into the field of view. Further observations did not bear this out, and nearly three decades of further data defied a consistent explanation. Different groups observing different emissions with different kinds of instrumentation at different times observed fundamentally different kinds of variability. In particular, variability of some ions appeared locked to System III, others appeared locked to "System IV" which is slightly slower, and still others showed no variability at all.

The Cassini UVIS instrument provided breakthrough observations during the Jupiter flyby on 2002 (Steffl, Ph.D. thesis, 2005). The progress can be attributed to UVIS' ability to observe all the major ions continuously for a period of months. Steffl's analysis revealed two key insights into torus longitudinal structures. First, the key longitudinal variation is ionization state, attributable to an asymmetric hot electron population. (This effect was also present in earlier HST observations.) Second, the UVIS observations detected distinct, comparable System III and System IV variations, and monitored their effects as they passed in and out of phase with each other. I will discuss how these insights explain the vast majority of previously inconsistent observations.

The Cassini results provide an empirical framework for describing the longitudinal structures, but as yet offer no clues as to why such structures exist. Specifically, the observations require two populations of hot electrons, one locked to a fixed magnetic longitude and another sub-corotating. We welcome discussion following this talk on (1) the origin of the two hot electrons populations, (2) the fixed location of one population in the torus, and (2) the cause of subcorotation of the other population.

This work has been supported by NSF's Planetary Astronomy Program.

-**INVITED-**

The Jupiter-Io Electromagnetic Interaction: Differences and Similarities to Earth's Aurora

Robert Ergun, Y.-J. Su, F. Bagenal, P. A. Delemere
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The Jupiter-Io interaction is, in many ways, analogous to the Earth's auroral region during a substorm. During the substorm expansion phase at Earth, enhanced magnetic reconnection launches intense Alfvén waves near the polar cap boundary. As these waves approach the Earth's ionosphere, they accelerate field-aligned electrons with a broad energy range which can cause some of the brightest visible aurora at Earth. The "Alfvén aurora" are highly variable and are not associated with a global, steady-state current system although they may contain intense, highly-filamented, local currents. As the magnetic field lines convect to lower latitudes, the "Alfvén aurora" give way to more classic auroral arc structures associated with parallel electric fields of the upward current region. At Jupiter, Io launches intense Alfvén waves from ion pick-up or from the electromagnetic interaction of Io's finite conductivity with Jupiter's rapidly rotating magnetic field. The brightest auroral emissions come on the Alfvén-dominated magnetic footprint. In the wake of Io, the Alfvén-dominated region transitions to a large-scale current system which brings the Io torus back toward co-rotation. Thus, the wake of Io is in many ways similar to Earth's current-driven aurora system.

-**INVITED-**

Ion Production and Transport Near the Galilean Moons

William R. Paterson(1), L. A. Frank(2), K. L. Ackerson(2)
(1) Hampton University
(2) University of Iowa

High-resolution measurements from the plasma instrumentation (PLS) of the Galileo spacecraft recorded during near encounters with the Galilean moons yield unprecedented evidence of complex phenomena associated with the motions of the moons through the magnetosphere. The plasma environment of each moon is unique, but all 4 moons exhibit evidence of local ion production. At Io, the ionosphere is nearly stagnant, and plasmas of the torus are effectively excluded from the flux tube connecting that moon to Jupiter. At Ganymede, complex streams of ions are observed in the wake of Ganymede's magnetosphere. At both Europa and Callisto, ions are dragged from the moons into the downstream region. At Europa the ions are nearly at corotation speed within a few thousand kilometres. At Callisto, the ions have speeds far below that of corotation. In this presentation we discuss these findings in the context of other past and recent work directed toward understanding the environments of the moons and their interactions with Jupiter and with Jupiter's magnetosphere.

Temporal and Azimuthal Variability in the Io Plasma Torus

A. J. Steffl, P. A. Delamere, and F. Bagenal
LASP/Univ. of Colorado

We present analysis of the observations of the Io plasma torus obtained with the Cassini Ultraviolet Imaging Spectrometer (UVIS) between 1 October 2000 and 14 November 2000. The Io torus is found to exhibit significant azimuthal variation in ion composition. This azimuthal compositional variation is observed to have a period of 10.07 hours---1.5% longer than the System III rotation period of Jupiter. While exhibiting many similar characteristics, the periodicity in the UVIS data is 1.3% shorter than the System IV period defined by Brown (1995). The mixing ratio of S II in the torus is found to be strongly correlated with the mixing ratio of S III and the equatorial electron density and anti-correlated with both the mixing ratios of S IV and O II and equatorial electron temperature. The amplitude of the azimuthal variation of S II and S IV varies between 5-25% during the observing period, while the amplitude of the variation of S III and O II remains in the range of 2-5%. The amplitude of the azimuthal compositional asymmetry appears to be modulated by its location in System III longitude, such that when the region of maximum S II mixing ratio (minimum S IV mixing ratio) is aligned with a System III longitude of ~200 degrees, the amplitude is a factor of ~4 greater than when the variation is anti-aligned.

Radial Variations of the Io Plasma Torus

Peter Delamere, Fran Bagenal, Andrew Steffl

Observations of the Io plasma torus were made by the Ultraviolet Imaging Spectrograph (UVIS) on the Cassini spacecraft during the flyby of Jupiter (October 2000 to March 2001). A full radial scan through the midnight sector was made on January 14, 2001, shortly after closest approach. The observed radial variations are described by Steffl et al. (2004) and provide electron temperature, plasma composition (ion mixing ratios), and electron column density as a function of radius from L = 6 to 9 as well as the total luminosity. We have advanced our homogeneous model (Delamere and Bagenal, 2003) to include latitudinal and radial variations in a manner similar to two-dimensional model by Schreier et al. (1998). The model parameters include: (1) neutral source rate, (2) radial transport coefficient, (3) the hot electron fraction, (4) hot electron temperature and (5) the neutral O/S ratio. The radial variation of parameters 1-4 are described by simple power laws, making a total of nine parameters. We explore the sensitivity of model results to variations in these parameters and compare the best fit with previous Voyager era models (Schreier et al., 1998), Galileo data (Crary et al., 1998), and Cassini observations (Steffl et al, 2004).

Relationship Between Jovian Magnetospheric Plasma Density and Io Torus Emissions

Hiromasa Nozawa(1), Hiroaki Misawa(2), Shin Takahashi(2), Akira Morioka(2), Shoichi Okano(2), Ravi Sood(3)
(1) Rikkyo University
(2) Tohoku University
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The ground-based observations of [SII] 673.1 nm emission from the Io plasma torus showed the year-to-year decrease between 1997 and 2000 (Nozawa et al., 2004). This phenomenon suggests that electron and ion densities in the plasma torus decreased during the period, since S+ ions are excited through electron impact. From the lower cut-off frequency of the trapped continuum radiations observed with the Galileo Plasma Wave Spectrometer (PWS), local electron density in the middle and outer magnetosphere (30-60 RJ) during C9 (1997), E16 (1998), C23 (1999) and G28 (2000) orbits was investigated. The periods of these orbits and our ground-based observations were almost overlapped each other. To reduce local time dependence of the electron density in the magnetosphere, we restricted the local time sector of the Galileo spacecraft between 18 and 00 hr. The electron density in the magnetosphere also showed long-term decrease between 1997 and 2000. This concurrent long-term variation of the magnetospheric electron density with the plasma torus emission would verify that the Io plasma torus controls the magnetospheric plasma environment as has been suggested since the Voyager era.

New Description of the Cold Torus

Floyd Herbert(1), N. M. Schneider(2), and A. J. Dessler (1)
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(2) LASP, U. of Colorado

New estimates of the distribution of S+ ions in the Io plasma torus have been derived by deconvolving the line-of-sight averaging from ground-based torus images taken by Schneider and Trauger [1995], revealing new details of the "ribbon" feature and cold torus. Whereas the radially thin ribbon is apparent only at the ansa, line-of-sight averaging through the greater radial width of the cold torus makes it visible at all longitudes, producing radial-longitudinal confusion in the images and greatly complicating analysis of images of the cold torus. By deconvolving the images, we have removed much of this confusion and revealed the cold-torus S+ distribution with new clarity.

The cold torus is washer-shaped, like Saturn's rings, but unlike the cylindrical ribbon. The small vertical (north/south) thickness of the cold torus does not vary greatly with System III longitude, in contrast with the ribbon, but its horizontal (radial) width varies by about a factor of 2. At longitudes near ~180, where the vertical height of the ribbon is smallest, the horizontal width of the cold torus is largest.

Contrary to the vague popular impression of the cold torus as a stagnant residue of old torus plasma that has merely diffused inwardly from the ribbon over the years, the cold torus has well-defined inner and outer edges. Moreover, it is separated from the ribbon by a well-defined 0.1-0.2R_J gap with density reduced by at least a factor of 2. Mechanisms that could produce such a puzzling structure need to be found.

Like the ribbon, the inner edge of the cold torus is closer to Jupiter at the dusk ansa; however the dawn-dusk difference between the cold-torus jovicentric distances is only about 0.2R_J, in contrast with the 0.3R_J dawn-dusk difference between ribbon distances. Thus the inferred dawn-dusk electric field is ~30% weaker at 5R_J than at the 5.5-6R_J ribbon distance, suggesting that it is a fringing field from a polar-region potential difference, consistent with its suggested origin from torus plasma flowing out the magnetotail. While the ribbon density varies with longitude by a factor of ~2 (with opposite phase from its height variation), the density of the cold torus varies in phase with its width variation, but only by about 15%.

We estimate that the ribbon is tilted by almost 1 degree away from the centrifugal equator (defined by the cold torus latitude) toward the magnetic equator (in rough agreement with Schneider and Trauger).

Reference: Schneider and Trauger, Astrophys.J. 450:450, 1995

Close-up Imaging of Sodium Escaping from Io

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The heavy ion population in Jupiter's magnetosphere is ultimately supplied by volcanic activity on Jupiter's moon Io. Gasses emitted from the volcanoes form a tenuous atmosphere around Io. This atmosphere, in turn, escapes from Io and is ionized, forming the plasma torus around Jupiter.

One of the uncertainties regarding Io's atmospheric escape is the spatial distribution of the escape flux over Io. From observations of the large-scale neutral clouds around Io, it is believed that atmospheric sputtering results in a nearly isotropic, slow outflow of neutrals. On the other hand, the high-speed sodium "jet" is believed to arise from ionospheric escape from Io's anti-Jovian hemisphere. The source location of the dissociating molecular pickup ion stream is more difficult to deduce since the molecular ions in question travel downstream of Io for hours before dissociating into neutrals which can be detected.

In order to localize the source regions around Io, we have used the 3.7-meter AEOS telescope on Mt. Haleakala to take spectral images of sodium emission within a few Io radii of Io. Preliminary analysis of data from December 2000 indicates that the highest neutral sodium densities were found downstream of Io, where we would expect to find the beginning of the dissociating molecular ion stream.

Jupiter-Io Interaction: Large Scale Current System Versus Alfven Dominated Region

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Three types of magnetosphere-ionosphere (MI) coupling processes in the Earth's auroral regions are suggested to be active on Jupiter as well: an upward current region, a downward current region, and an Alfven-dominated region. The Io-controlled Jovian aurora shows evidence of Alfven-dominated aurora in the footprint of Io, while the extended tail emissions at Io's wake are due to electron acceleration from parallel electric field in an upward current region. Results from a one-dimensional quasi-steady Vlasov code suggest that in spite of the differing boundary conditions and the large centrifugal potentials at Jupiter, the auroral cavity formation may be similar to that of the Earth and that parallel electric fields may be the source mechanism of Io-controlled decametric radio emissions. Results from a linear large-scale gyrofluid model indicate that the majority of Alfven wave energy is unable to reach Jovian ionosphere without wave breaking, phase mixing, or other nonlinear processes; however, small wavelength/high frequency waves are able to reach the Jupiter's ionosphere. Furthermore, an Alfven eigenmode, called the ionospheric Alfven resonator, can develop between the conducting boundary of Jupiter and the exponential increase in Alfven velocity on the topside of ionosphere. The frequency of the Alfven resonator is comparable to the observed reoccurring frequency of S-bursts. Hence, we suggest the Alfven resonator as a possible driver explaining multiple occurrences of S-bursts.

Current Wing Solutions in an Inhomogeneous Medium

Duane Pontius
Birmingham-Southern College

The observed correlation between a localized auroral spot and the magnetic footprint of Io establishes a causal relationship between the two, but the physical details of the interaction remain unclear. The Alfvén wing model [Neubauer, 1980; Goertz, 1980] does not permit the propagation of information from the ionosphere back to Io because its solutions are restricted to perfectly incompressible flows in an unbounded, homogeneous medium. In contrast, the current wing model [Pontius, 2002] assumes that the flow is nearly incompressible rather than perfectly so, which provides a richer and more flexible family of possible solutions. Approximate solutions to the non-linear governing equations are obtained by solving Poisson's equation in the plane perpendicular to the wing axis, which need not be along the local Alfvén characteristic. Density variations along the wing are modelled by continuously varying through a series of these solutions. Thus, a persistent two-way connection between Io and Jupiter can be maintained even in the absence of perfect shielding by Io

Studies of Io's Nonlinear MHD-Wave Field in the Inhomogeneous Jovian Magnetosphere

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Ultraviolet and infrared imaging dramatically illustrate the interaction between Io and Jupiter. The different magnetohydrodynamic (MHD) waves generated by Io propagate through the dense plasma torus, the low density magnetospheric plasma and finally reach the Jovian Ionosphere producing the well-known Io footprint. The magnetospheric model introduced is a nonlinear, three-dimensional, time dependent MHD code, idealized by assuming straight field lines in the initial and upstream condition. The simulations are carried out for a range of interaction strengths or wave amplitudes produced by varying the density of a spherical cloud of neutral gas representing Io. Thus we are able to study the transition from linear to strongly nonlinear interaction and observe profound differences. We show that the nonlinear description is of particular importance since field and plasma in the vicinity of Io and its Alfvén Wing are strongly disturbed. Moreover the various MHD-wave modes interact with each other as well as with the multiple reflections and transmissions originating from the several plasma density gradients and thus demand nonlinear treatment. The emphasis is rather put on the basic physics of nonlinear wave propagation, reflection and transmission instead of realistic modelling of Io's environment. However structural features like the shape of the Io footprint wake can be compared to measured data. These results are also applicable to the inner icy satellites of Saturn like Enceladus.

Location and Morphology of Io's FUV Footprint Emissions on Jupiter

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FUV imaging of Jupiter's aurora with the Hubble Space Telescope has shown that the northern main oval has a distorted shape in the general range of 90-140º System III longitude, which appears unchanged since 1994. While it is more difficult to observe the conjugate regions in the southern aurora, no corresponding distortion appears to be present in the south. Recent improved accuracy in locating the satellite footprint emissions has provided new information on the geometry of Jupiter's magnetic field in this and other areas. Such information cannot currently be obtained from in situ measurements made with orbiters. Most UV images also reveal a long trailing emission downward of Io's magnetic footprint, which is associated with Io's wake plasma. We discuss the location of the Io footprint and the brightness distribution of the tail, with an emphasis on the occurrence of multiple footprints, derived from the most recent HST observations. We show that the footprint brightness varies considerably, not only with the distance from the central meridian, but it also shows intrinsic intensity changes possibly linked to the location of Io in the torus.

Europa's Neutral Cloud: Modelling Galileo and Cassini Observations

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The interaction between high energy ions in Jupiter's magnetosphere and Europa's icy surface results in the sputtering of water, its dissociation products, and minor species trapped in the ice. Hydrogen escapes from Europa, forming a neutral torus around Jupiter, while most of the oxygen is gravitationally bound and has been detected in Europa's atmosphere. Galileo observations coupled with Cassini measurements during its Jupiter flyby now suggest that the hydrogen component of this sputtered material has also been detected. Lagg et al. (2003) reported the depletion of protons with pitch angle 90 degrees near Europa consistent with the loss of protons due to charge exchange with an equatorially confined cloud of neutral gas. Mauk et al. (2003) detected the energetic neutrals which result from this charge exchange.

We present models of the distribution of hydrogen and oxygen lost from Europa's surface and atmosphere, focusing on the material with sufficient energy to escape from Europa. These studies use recent models of Europa's atmosphere (Shematovich et al. 2004) to estimate the escape rates and initial energy distributions of sputtered material, and an empirical description of the Io plasma torus (described in Burger 2003) to determine ionization rates in Jupiter's magnetosphere. We compare the resulting non-uniform distributions with the published spacecraft observations to constrain the total amount of material lost from Europa's surface. We also discuss the effects of spatially non-uniform surface sputtering on the large scale morphology of Europa's neutral cloud.

This work has been supported by grants from NASA's Planetary Atmospheres and Outer Planets programs.

References:

Burger, M.H. Ph.D. Thesis, University of Colorado, 2003.
Lagg, A., Krupp, N., Woch, J., Williams, D.J. GRL, 30, 10-1, 2003.
Mauk, B.H., et al. Nature, 421, 920, 2003.
Shematovich, V. I., et al., Icarus, 173, 480, 2005.

A Comparative Analysis of Satellite Influenced Radio Emission from Jupiter: Voyager, Galileo, and Cassini

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Observations from both the Galileo and Voyager spacecraft show the influence of the four Jovian satellites on the radio emission generated in the Jovian magnetosphere. Statistical analyses of Jupiter's emission intensity and occurrence probability with satellite orbital phase shows a significant correlation for all four Galilean satellites.

Data from the Cassini spacecraft flyby at Jupiter will be added to to compare and confirm these results in different frequency bands. All three spacecraft data will be compared and presented to address the nature of these satellite-magnetosphere interactions.

Quantification of Ganymede's Magnetosphere Including the Role of Ion Cyclotron and Heavy Ion Effects

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Heavy ions are very abundant in Ganymede's near-space environment, with the Jovian magnetosphere, Io torus and Ganymede's own ionosphere providing a variety of species of different mass and at different energies. The importance of the role of ion cyclotron motion in governing the shape and dynamics of Ganymede's magnetosphere has been generally acknowledged, but not typically included in global models of Ganymede. In this study we examine these effects in the framework of multi-fluid simulations. Multi-fluid simulations can track the density, heating and motion of each of the various ion species thought to be present in Ganymede's near space environment. Because the heavy ion-weak magnetic field environment present at Ganymede, the ion skin depth/ion gyro-radius can be comparable to the scale size of critical boundary layers, and the standard assumptions of ideal MHD are not valid. It is shown that these effects lead to a significantly larger and more asymmetric magnetosphere. These changes are sufficiently large that they can be seen in comparisons with flyby magnetometer data from Galileo. The simulations show closest agreement when a full treatment of ion cyclotron and heavy ions effects are incorporated. The utility of the multi-fluid treatment is also evident in the ability to study and interpret the particle distributions as determined by Galileo PLS measurements.

Time Varying Interaction of Europa with the Jovian Magnetosphere

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Galileo measurements acquired on several passes by Europa indicate the existence of an electrically conducting ocean in the interior of the satellite. As a consequence of the synodic period of Jupiter, the magnetic field and the magnetospheric plasma at Europa are varying periodically. The time varying magnetic field induces currents in the interior of Europa which cause an induced magnetic field influencing the plasma interaction. Therefore the magnetospheric plasma and magnetic field interact with the thin atmosphere and ionosphere of Europa and with the time varying induced magnetic field from the interior of the satellite.

We develop a time dependent 3D MHD model in order to investigate the periodic temporal variations of the interaction between the satellite and the Jovian magnetosphere. Compared to stationary models, we include in our model periodic magnetic fields from the interior of Europa, caused by electromagnetic induction in the conducting ocean below the icy surface of Europa. In addition to the induction by the time varying magnetospheric background field we also account for the periodic variations of the magnetospheric plasma at Europa which leads to a second order induction effect. Results are compared to magnetic field data of the Galileo encounters with Europa.

The Juno New Frontiers Jupiter Polar Orbiter Mission

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The Juno mission has been selected as the 2nd New Frontiers Mission. The mission is a Jupiter polar orbiter which launches in 2009, arriving at Jupiter in 2014, for a one year orbital tour. Juno's investigation of Jupiter focuses on four themes: origin of Jupiter, interior structure, atmospheric composition and dynamics, and the polar magnetosphere. Juno's 32 orbits extensively sample Jupiter's full range of latitudes and longitudes. High sensitivity radiometric measurements yield a 3-dimensional view of Jupiter's deep atmosphere to infer the bulk abundance of water, and understand its complex meteorology. The gravity data constrain the planet's interior rotation and structure. The precise magnetic field measurements are used to infer how the interior dynamo works and generates the most powerful magnetic field of planets in the Solar System. From its polar perspective Juno combines in situ and remote sensing observations to explore the polar magnetosphere and determine what drives Jupiter's remarkable auroras.

An overview of the Juno investigation will be presented.

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Posters

Monday and Tuesday

Jovian Magnetospheric Scale and Polar Cap Magnetic Flux Dependent on Solar Wind Dynamic Pressure

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Subsolar jovian magnetopause pressure balance between solar wind and model magnetospheric field and plasma determines the jovian magnetospheric size. All inner magnetospheric magnetic field sources in the present model are screened by the magnetopause currents. It guarantees a zero normal magnetic field component for the inner magnetospheric field at the whole magnetopause surface. By changing magnetospheric scale (subsolar distance), the model gives a possibility to study the solar wind influence on the magnetospheric structure and auroral activity. A dependence of the magnetospheric size on the solar wind dynamic pressure psw (inversely proportional to pressure in the one fourth power) is obtained. A polar cap magnetic flux also depends on the solar wind pressure and is inversely proportional to magnetopause subsolar distance.

The Large Scale Jovian "Magnetopause Boundary Layer" of Energetic Ions and Electrons: Ulysses, Pioneer 10 And 11 And Voyager 1 And 2 Observations Re-examined

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The existence of a large scale layer of ions and electrons in the high latitude Jovian magnetosphere has been strongly suggested by the analysis of various particle (including plasma and relativistic electron) observations by during Ulysses flyby of Jupiter; we call the layer of Energetic Particles as "Energetic Particle Magnetopause Boundary Layer" (EP-MPBL). In the duskside south magnetosphere, outbound, Ulysses crossed this layer from ~49 to ~83 R_J (throughout a distance as large as ~34 R_J). Elaboration of cross-field anisotropies well outside the magnetodisk, during Ulysses inbound and outbound trajectory, indicates intensity gradients in the direction (not toward the magnetodisc, but) toward the high latitude magnetosphere. The energetic particle (including relativistic electron) observations show energy dependent intensity gradients within this layer, in the direction from the magnetopause toward the interior edge of the layer (with more intense gradients and hardening of the spectrum near the magnetopause). As a consequence of the ~10 hour rotation of the Jovian magnetosphere and the flux-spectral changes within the EP-MPBL, ~10 variations in the spectrum and the cross-field anisotropy (due to intensity gradients) were observed. A re-examination of data obtained by previous missions (Pioneer 10 and 11, Voyager 1 and 2) indicates that a similar EP-MPBL was also present at those times and strongly suggests that the EP-MPBL is rather a permanent feature of the Jovian magnetosphere. The new model proposed for the Jovian magnetosphere explains the well known ~10 hour rocking of the relativistic electron spectral index outside the magnetodisk.

Continuous Periodic (~48 Min) Energetic Particle Modulation in the Equatorial Predawn Jovian Magnetotail Between Days 192-202, 1979

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The quasi-periodic ~40 min series of beams is one of the most important findings of Ulysses Jupiter's magnetosphere investigation. Furthermore, quasi-periodic particle pulses due to oscillations of the magnetodisc have also been reported both inbound and outbound (Schulz et al., 1993; Anagnostopoulos et al., 2001). Re-examination of energetic particle observation from the LECP experiment onboard Voyager 2 reveals a persistent periodic ion spectral modulation at ~48 min, superimposed on the ~10 h modulation caused by magnetodisc encounters. This ~48 min spectral modulation was evident for more than 10 days (d192-202, year 1979) as long as the spacecraft moved in the equatorial magnetotail all the way from ~30 to ~150 R_J. The ~48 min modulation was observable in energetic particle (LECP), cosmic ray (CRS) and magnetic field (MAG) observations, and was more evident during plasma sheet crossings. The modulation was observable in various kinds of particle species: protons, heavy ions and electrons. Higher frequency periodicities (~10-15min) were also found in several cases during the 11 days interval examined. The quasiperiodic48 min softening of the ion spectrum was observed in phase with ion flux minima and magnetic field magnitude maxima. We infer that the LECP observations are consistent with a principal pulsation of the Jovian magnetosphere during Voyager2 exploration of the predawn equatorial magnetotail at ~48 min, and with (periodic~48 min) encounters of the spacecraft with energy dependent intensity gradients in the magnetodisc.

Absorption of Relativistic Electrons by Orbiting Jovian Dust

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The Galileo spacecraft operated in its high time resolution mode in the 6 to 2.5 R_J jovicentric distance on its next to last (A34) orbit. The Energetic Particle Detector (EPD) instrument acquired data over its full range of angular positions while the spacecraft rotated about its Earth-oriented axis. Several channels of EPD designed to measure high energy electrons directionally through a passive collimator also respond to radiation of sufficient energy to penetrate the shielding of the detectors. Several of the orientations of the EPD instrument point the collimator axis parallel to the Galileo rotation axis so that variations of channel response due to foreground (through the open aperture) radiation are not expected. However, periodic variations of channel counting rate synchronous with Galileo rotation are observed systematically in the several coaxial collimator orientations. We interpret these variations as being due to penetrating radiation interacting with a non-axisymmetric response function of these channels. The patterns observed suggest that the penetrating radiation, presumed here to be relativistic electrons, changes its angular distribution from being peaked at 90 degrees to the local magnetic field to peaking away from 90 degrees at a radial distance from Jupiter of about 3.8 RJ. An interpretation of this that we presently favour is that orbiting solid material is sufficient to preclude a pitch angle distribution of penetrating radiation peaking at 90 degrees to the magnetic field at low magnetic latitudes.

Paraboloid Model of Jupiter's Magnetospheric Magnetic Field

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Numerous studies have shown that the size and shape of the Earth's magnetopause depends significantly on the properties of the upstream interplanetary medium, principally the dynamic pressure of the solar wind and the north-south component of the interplanetary magnetic field. For the case of Jupiter's magnetosphere the relative paucity of in situ data compared with Earth has meant that the size and shape of the magnetosphere have only been investigated with respect to the solar wind dynamic pressure. The effects of the IMF direction on the size and shape of the jovian magnetopause have not yet been determined directly using in situ data. However, we may expect that similar effects occur as observed at Earth, except for the opposite sign of IMF BZ due to the opposite sense of the equatorial planetary field. In this paper we present a new model of the jovian magnetosphere in which the flaring of the magnetopause boundary can be varied. The model includes a tilted dipole field which is screened by the magnetopause, a tail field current system, and the field of a screened equatorial current disc.

IMF Influence on the Jovian Magnetospheric Plasma Dynamics

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The jovian magnetospheric magnetic field model is constructed. This model allows one to calculate plasma motions and electric fields caused by the Jupiter rotation and the solar wind MHD generator. Calculations in the constructed model show that for southward IMF, in the equatorial magnetospheric plane, the anti-corotational and anti-sunward flows occur in the dawn sector, and anti-sunward flows in the same sense as corotation arise in the dusk sector. Contrary to the case of southward IMF, for northward magnetic field of the solar wind, the corotation exists in the equatorial magnetospheric plane up to the subsolar point. The corotation electric field equipotentials form a vortex structure not only in the equatorial magnetospheric plane, but also on the northern and southern halves of the magnetopause. Beyond the neutral line in the magnetotail the anti-sunward plasma flows caused by the solar wind electric field dominate.

Synchronized Oscillations in Whistler Wave Intensity and Energetic Electron Fluxes in Jupiter's Middle Magnetosphere

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Synchronized oscillations in whistler wave intensity and energetic electron fluxes at the planetary rotation period have been observed in and near Jupiter's magnetosphere. In this work we theoretically examine time-dependent processes in Jupiter's middle magnetosphere energetic electron radiation belts which are relevant to these oscillations, where intervals of particle accumulation are followed by precipitation into the ionosphere during a whistler electromagnetic radiation pulse. These oscillations are described by a relativistic system of quasilinear equations, in which diffusion of particles in adiabatic invariant space and evolution of the electromagnetic radiation are taken into account. Linear analysis shows that the natural oscillation frequency of the jovian radiation belt is almost independent of magnetic shell, and is close in magnitude to the planet's rotation frequency, thus suggesting the possibility of a global resonance. We propose that such near-resonant oscillations can be excited by periodic modulations of the whistler decay rate due to ionospheric absorption, which has components that depend both on local time in the magnetosphere and on asymmetries that rotate with the planet. These dependencies are shown to combine to produce a modulation at the planetary rotation period that is independent of local time, and also independent of the angular velocity of rotation of the plasma. The response to this synchronized driving is investigated in both the linear and nonlinear regimes, and the conditions required for a synchronized response at the planetary period are examined.

Modelling The Radial Structure of the Plasma Disk in Jupiter's Magnetosphere

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Stability of the background plasma disk in Jupiter's magnetosphere with respect to the flute perturbations is considered. To take into account coupling with the well-conducting planetary ionosphere and the rarefied plasma regions outside the disk, the following model was suggested. It is assumed that relatively dense plane plasma disk borders on regions of rarefied magnetospheric plasma, which contact with the planetary ionosphere. The experimental and model data on the radial distributions of the magnetic field strength and plasma angular velocity in Jupiter's middle magnetosphere are used. In the framework of the model the flute instability can occur in the dense disk due to the action of centrifugal force. An exact dispersion relation of the plasma perturbations in the case of the perfectly conducted ionosphere is obtained. Analyzing starting conditions of the flute instability in the disk, the "threshold" radial profile of the plasma density is determined: any more steep profile is unstable with respect to the flute instability. As shown, the "threshold" distribution of the plasma density roughly corresponds to the magnetic field strength profile with a factor depending on the ratio of the plasma densities outside and inside the disk. An application of the results obtained to the known data on the jovian plasma disk is discussed.

Io's Interaction With the Magnetosphere of Jupiter

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The interaction between Io's atmosphere and Jupiter's magnetic field leads to a plethora of phenomena. Yet no present theory or model is capable of unifying the underlying physical processes that generate (1) the ton/second that fills the giant magnetosphere, (2) auroral emissions excited in both Io's and Jupiter's atmosphere, (3) radio emissions that are triggered when Io is at certain locations, and (4) neutrals that form a corona around Io and extend as tenuous clouds up to AU away from Jupiter. Observations of the radio and auroral emissions (i.e. radiated power) together with remote and in situ measurements of the plasma torus (i.e. composition and radiated power) provide constraints for the flow of energy, momentum, and mass through the system. We seek to answer three basic questions: (1) How does the plasma source at Io depend on the neutral cloud distribution and on the impinging plasma conditions? (2) To what extent is the local interaction influenced by mass loading and/or by Io's ionospheric currents? (3) How is energy and momentum transferred between Io and Jupiter? We will compare Galileo's in situ measurements with near-Io "flybys" (i.e. where the flow is not significantly slowed) of our physical chemistry model (Delamere and Bagenal, 2003) and discuss progress on a three-dimensional, self-consistent model of the plasma interaction using a hybrid code.

The NASA Radio JOVE Project: Impact in the Classroom

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The Radio JOVE project (http://radiojove.gsfc.nasa.gov) is an education and outreach project intended for students to interactively perform basic radio astronomy observations. With the kit ($155 + shipping) students create a radio telescope by building a receiver and antenna that operate at a frequency of 20.1 MHz. They can then receive signals from Jupiter, the galaxy, the Sun, and a variety of manmade and terrestrial radio noise. The kits appeal to individuals of all ages who want to learn about radio astronomy. Chart recorder emulation software, called Radio-Skypipe, http://radiosky.com, allows anyone to monitor in real time others who are sending out their signals using Radio-Skypipe. Spectrographs covering 200 frequencies from 18 to 28 MHz have been developed and connected to professional radio telescopes in Florida and Hawaii. Radio JOVE began with NASA funding nearly seven years ago and has distributed over 750 kits worldwide. During this time the Radio JOVE kits have been used for a number of science fair projects, summer research and classroom projects. Through teacher and student interactions with scientists, Radio JOVE is making an impact. We will overview the Radio JOVE project and attempt to quantify the science impact in the classroom.

Jupiter's Decametric Radio Active Region Measured by the Modulation Lane Method

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Frequency-time dynamic spectra of Jupiter's decametric radio emission display a complex structure on several different time scales. One of the characteristic spectral patterns on a time scale of a few tens of seconds are the modulation lanes discovered by Riihimaa in 1968. We developed a model for the mechanism responsible for their production in which the free parameters can be adjusted to provide a very close fit with the observations [Imai et al.,1992a,1992b,1997,2002]. In our model, we propose the existence of a grid-like interference screen composed of field-aligned columns of enhanced or depleted plasma density located along the longitudinal direction near Io's orbit.

We made a statistical analysis of Io-A and Io-B source modulation lanes observed by wideband spectrographs at Oulu, Florida, and Nancay. Using the modulation lane method it was possible to make relatively precise measurements of the value of the cone half-angle of the hollow-cone emission beam and the System III source locations for the Io-A and Io-B sources. The measured cone half-angles for the two sources were both within about 3 degrees of 60 degrees. The measured typical ranges of source System III longitude are 130 to 205 degrees for Io-A and 125 to 215 degrees for Io-B. These results show that the radio active regions of Io-A and Io-B are sharing the same source System III longitude. Based on these results, we are able to show for the first time a more realistic view of the location and beaming of Jupiter's radio sources using a 3D computer graphic animation (http://jupiter.kochi-ct.jp/cg/). This can provide a very important piece of information in the investigation of the mechanism responsible for Jupiter's decametric radio emission.

References

[1] A Model for the Production of Jupiter's Decametric Modulation Lanes, K.Imai, L.Wang, and T.D. Carr, Geophysical Research Letters, Vol.19, No.9, pp.953-956, 1992a.
[2] Origin of Jupiter's decametric modulation lanes, K.Imai, L.Wang, and T.D. Carr, Planetary Radio Emissions III, edited by H.O. Rucker and S.J. Bauer, Austrian Academy of Sciences, Graz, Austria, pp.69-90, 1992b.
[3] Modeling Jupiter's Decametric Modulation Lanes, K.Imai, L.Wang, and T.D. Carr, Journal of Geophysical Research, Vol.102, No.A4, pp.7127-7136, 1997.
[4] Measurement of Jupiter's Decametric Radio Source Parameters by the Modulation Lane Method, K.Imai, J.J.Riihimaa, F.Reyes, and T.D. Carr, Journal of Geophysical Research, Vol.107, No.A6, 10.1029/2001JA007555, 2002.

Jupiter's Main Auroral Oval and High-Latitude Emissions Structure

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Jupiter's auroral oval and high-latitude luminosity structure are investigated on the base of the model of Jovian magnetosphere, which describes magnetic field as a sum of the internal and external magnetic fields represented by the VIP4 model and by paraboloid model, respectively. The magnetodisc, tail and magnetopause currents, as well as the IMF penetrated to the magnetosphere are the main sources of the magnetic field in terms of paraboloid model. The calculated in the system III planetocentric coordinates southern and northern main ovals are located close to the main reference ovals obtained from observations. It is shown that calculated main auroral oval which is traced from the inner edge of the magnetodisc located at the equatorial distances of $20R_J$ is determined mainly by the internal Jovian magnetic field and is not practically influenced by the external one. The magnetodisc currents variation change the main oval size by 1-2 degrees. The auroral oval area obtained from measurements can be used to estimate the magnetodisc currents intensity. It is shown that the high latitude footprint traced from the outer edge of the magnetodisc forms the inner oval, which is controlled by the IMF Bz and is located poleward from the main oval by approximately 5 degrees. It is suggested that transpolar emission and arcs observed often in the high latitude Jovian ionosphere inside the main oval could be the fragments of this inner oval. The main auroral oval rotates with the planet relatively the direction to the Sun. It is found that the area with angular radius of 5 degrees fixed in jovian solar-magnetospheric coordinates exists ed around the magnetic pole. It could be associated with the region of the open field lines or field lines traced to the distant tail.

Small Jovian Orbiter for Magnetospheric & Auroral Studies

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Solar-Sail Project examined by ISAS/JAXA as an engineering mission has a possibility of a very small probe into the Jovian orbit. This paper summarizes the basic design of Jovian magnetospheric and auroral studies by this chance.

A large-scale Jovian mission has been a hope since the 1970s when the examinations of planetary exploration were started in Japan. In one of the plans, the largest planet in the solar system would be solved by two main objectives: (1) Structure of a gas planet: the internal & atmospheric structures of a gas planet (following the objectives of Planet-C and BepiColombo). (2) Jovian-type magnetosphere: the process of the strongest magnetospheric activities in the solar system (following the objectives of BepiColombo and SCOPE). The small Jovian orbiter in the Solar-Sail Project aims to establish the feasibility of such future by ISAS/JAXA.

The Radial and Local Time Structure of Jupiter's Current Sheet

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We use magnetic field data from the six spacecraft that have visited Jupiter's magnetosphere and new techniques to determine the structure and thickness of Jupiter's current sheet. We determine the prime longitude (the system III direction in which the current sheet has its highest elevation), elevation angle and thickness of the current sheet as a function of both radial distance and local time. We find as previously discovered, the current sheet is delayed (i.e. its RH system III longitude is reduced) proportionally to the radial distance but we now show that the delay is systematically larger in the dawn sector compared to its value in the dusk sector. We relate the delay of the current sheet to the structure of Jupiter's magnetospheric field and to the Alfven wave travel time. Next, we determine the elevation angle of the current sheet and show that the current sheet becomes parallel to the solar wind flow at large distance.

Finally we determine the thickness of Jovian current sheet by modelling the magnetic field and show that the current sheet is much thicker on the dusk side compared to its value in other local time sectors. We will speculate on physical mechanisms that cause local time variations in the thickness of Jupiter's current sheet.

Source Characteristics of Jovian Quasi-Periodic Burst

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Quasi-Periodic burst (QP burst) was first discovered by Voyager and its detailed characteristics were reported by Ulysses observations when Ulysses flew by Jupiter in February 1992. QP burst has tens of minutes periodicity and frequency range from VLF to LF. Ulysses/URAP detected two kinds of QP burst, which have 15min and 40min periodicity, and they were named QP15and QP40 burst, respectively. It was also reported that energetic MeV electron bursts accompanies QP40 bursts. Previous studies suggested that source region of QP burst is located on the polar cap region. Apparent source location of QP burst, periodicity of 40min/15min, and acceleration process of energetic particle which may generate QP burst, however, are still unknown. To determine the location of source region and directivity of QP burst, we statistically analyzed the occurrence probability of QP burst with respect to the Jovian magnetic latitude and System III longitude, using the URAP data during the period of the Ulysses' second encounter with Jupiter. Analyzed result which covers latitudes from N10°to N80° revealed very characteristic structure of occurrence probability. We will reproduce the distribution of occurrence probability of QP burst by using ray tracing method.

Origin of Io Related Jupiter's Decametric Radiation Based on a 3D Ray Tracing Analysis : Consideration of the Source Locations with a Wide Longitudinal Range

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The Io-related Jupiter's decameter wave emission (Io-DAM) is known to show two clear occurrence characteristics. One is the occurrence periodicity and another one is the polarization characteristics. The former is that the Io-DAM events occur in specific geometric combinations of the central meridian magnetic longitude (CML) and Io phase angle. The latter is that most of the Io-DAM events show highly elliptical and RH dominant polarization, and each Io-DAM source shows different ellipticity.

We have made a 3D ray tracing analysis for Io-DAM to investigate the observed occurrence periodicity and polarization characteristics using the VIP4 magnetic field model and several plasma density models. In the analysis, we assumed that source locations of Io-DAM are located on the magnetic field lines in the wide longitudinal range instead of a limited source region which has been generally adopted in the previous ray tracing studies. This assumption is supported by the recent imaging observations in UV and/or IR wave ranges for Jupiter's auroras which showed that the existence of bright trails and/or bright periodic structures downstream of the foot of the Io flux tube.

As the result of the analysis, the observed occurrence probabilities of Io-DAM can be interpreted as follows; 1)Io-DAM is R-X mode wave, 2)Io-DAM is radiated quasi-perpendicularly to the local magnetic field with a small angle width, and 3)Io-DAM waves should be generated on some restricted magnetic longitudes. On the other hand, the observed polarization characteristics can be explained as follows in addition to the conditions of 1)-3); 4)Io-DAM propagates in quite tenuous plasma in Jupiter's upper ionosphere, and 5)plasma condition should be different between the polar upper ionospheres for Io-A and Io-B sources, that is, plasma density in the dusk side ionosphere for the Io-A DAM propagation paths is expected to be much larger than that in the dawn side ionosphere for the Io-B DAM propagation path.

Variations of Jupiter's Synchrotron Radiation below 2.3GHz

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Jupiter's synchrotron radiation (JSR) is an important probe to investigate generation and dissipation processes of the relativistic electrons and deformation of their global distribution in the radiation belt, where in-situ measurement is hardly effective. Regular and systematic JSR observations have been made by several groups including us and revealed the existence of short term variations at a time scale of several days to months inferring some unidentified electro-magnetic processes which might cause rapid radial diffusion in the inner magnetosphere.

A program of a multi-frequency observation for JSR has been started since 2001. The JSR spectrum measurements give us information of variations of pitch angle and/or characteristics of radial diffusion of the relativistic electrons. In this program three observation frequencies measured with different facilities have been adopted; i.e., 325MHz at Tohoku Univ., Japan, 929MHz at EISCAT, Sweden and 2.25GHz at NICT, Japan. JSR at the frequency range is generated from the relativistic electrons at the typical energy from 6 to 20MeV in the inner magnetosphere, and has been hardly observed regularly. Approximately 2 week successive JSR observations have been made in October, 2003 and July, 2004 at the three frequencies. A preliminary analysis for the spectrum observation shows a small variation of JSR flux density. In particular, it seems that the variation showed frequency dependence on both amplitude and timing; i.e., amplitudes of the variation were larger in lower frequencies and timing was delayed in higher frequencies.

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Plasma Flows and Currents in Jupiter's Polar Ionosphere

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We consider a simple axi-symmetric model of the plasma flows and currents in the jovian polar ionosphere, in a manner similar to that proposed for the Saturn system by Cowley, Bunce and O'Rourke (2004). The decrease of the plasma angular velocity with latitude from near-rigid corotation in the region mapping to the inner magnetosphere is based on that calculated previously by Nichols and Cowley (2004), who solved the Hill-Pontius equation in conjunction with a model for the dependence of the ionospheric Pedersen conductivity on auroral electron flux. The model is now extended to include flows mapping to the outer magnetosphere, the vicinity of the open-closed field line boundary, and the solar wind. Two models of flow in the outer magnetosphere are considered, based on spacecraft flyby measurements. In the first the plasma velocity is considered to be constant at ~25% of rigid corotation throughout the outer magnetosphere, while in the second the plasma velocity is 50% of rigid corotation in this region, possibly representing typical conditions during differing states of radial extension of the magnetosphere. The plasma angular velocity then decreases across the open-closed field line boundary to ~10% of rigid corotation on open field lines based on the model of Isbell et al. (1984). Solutions for the current and auroral parameters are presented for an assumed constant ionospheric conductivity, and for a model where the conductivity is modulated by accelerated electron precipitation in regions of upward field-aligned current. Results are compared with those for the corresponding model for Saturn.

Characteristics of Long and Short Term Variations of the Jovian Synchrotron Radiation at a Frequency of 327MHz

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The Jovian synchrotron radiation (JSR) is a radio wave emitted from the relativistic electrons in the Jovian radiation belt, which has information of dynamics of high-energy particles and electromagnetic disturbances in the Jovian inner magnetosphere. The intensity variation of JSR, however, has been little understood in its timescales and origin. We have observed JSR for several months a year since 1994 to reveal characteristics of the flux variations especially at the time scales of days to months (short-term) and years (long-term). The regular observations have been made at a frequency of 327MHz by using parabolic cylinder antennas of the Solar Terrestrial Environment Laboratory, Nagoya University. The observed JSR flux includes apparent variation due to inevitable system gain variation of the radio receiving system. In order to compensate the system gain variation, we have evaluated system gain using a flux reference radio source that was observed quasi-simultaneously with JSR, and made observations of 'actual' galactic back-ground radiation with a highly stable radio receiving system of Tohoku University.

As the result, we derived the JSR flux densities for 1994 - 2003 successfully and confirmed significant flux variations in both short and long time scales. In the presentation, we will introduce characteristics of the JSR flux variations and infer causalities of the variations based on correlation analyses between the flux variations and parameters of solar activity and solar wind.

Implication for the Solar Wind Effect on the Io Plasma Torus

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From the long-term ground-based observations of the plasma torus emissions between 1997 and 2000, we found sporadic enhancements of the [SII] 673.1 nm emissions in 1998 and 1999 (Nozawa et al., 2004). Common characteristics of the enhancement are i) emission intensity shows, at least, a factor of 2 increase, ii) emission scale height of the ribbon becomes smaller; iii) the enhancement occurs in the specific System III longitude range of between 120 and 180 degrees. However, all emissions in this longitude range do not always show this kind of enhancement, indicating that some additional trigger is necessary. During the enhancement observed on September 21, 1999, the Galileo spacecraft had been in the C23 orbit and carried out observations. Just after the enhancement of [SII] emissions, narrowband kilometric (nKOM) radiations suddenly appeared on the frequency-time spectrogram of the Galileo Plasma Wave Spectrometer (PWS). On the same day, so-called "auroral flare" was observed with the Space Telescope Imaging Spectrograph (STIS) onboard the Hubble Space Telescope (Waite et al., 2001). The auroral flare occurred on the same System III longitude range of the sporadic enhancement of [SII] emissions. It has been suggested that both sudden appearance of nKOM radiations and auroral flare are strongly related to the dynamic change of the solar wind pressure at Jupiter (Reiner et al., 2000; Waite et al., 2001). Although there are some ambiguities in the mechanism that connects these events, variation in the dynamic pressure of the solar wind is one of the probable triggers of the sporadic enhancement of the plasma torus emissions. If they have relations, ionosphere should play important roles to transmit information on the solar wind disturbance to the inner magnetosphere.

Jupiter's Magnetospheric Plasma Populations in Regions Conjugate to the Aurora

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Measurements of thermal plasmas from Jupiter's plasma sheet and plasma torus provide context for consideration of auroral processes. It is now thought by many that the main ring of auroral emission at Jupiter is a response to the breakdown of corotation in the middle magnetosphere and that the emissions are associated with the system of electric currents that communicate stresses between the ionosphere and the magnetosphere. Several mechanisms have been proposed to account for the transfer of energy that drives the IR, visible, and UV emissions. In this report we review observational evidence of the breakdown of corotation, and we report on the occurrence of field-aligned streams of hot electrons that may be a signature of processes in the ionosphere. We consider implications for models of magnetosphere-ionosphere coupling at Jupiter.

Ion Acceleration by Alfven Waves: Implications for the Energetic Ion Composition in the Jovian Magnetosphere.

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Galileo, as the first orbiting spacecraft around Jupiter, provides the opportunity to study globally and in an extended energy range the plasma composition of the Jovian magnetosphere. Analyzing data from the Energetic Particles Detector onboard Galileo, we study the relative ion abundance ratios of S/O, S/He, O/He and H/He at various energy/nucleon. The ion abundance ratios exhibit a strong energy dependence, resulting in a change of the ion energy spectra from a harder to a softer one at energies of several 100 keV/nucleon. This distinct spectral feature can be possibly explained by a steady state process in which the Jovian energetic ions interact with intense Alfven waves propagating along the magnetic field.

Radial Profiles of Aurora Near Io Observed with HST/STIS: Io's Ionospheric Properties

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(1) Southwest Research Institute
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The electrodynamic interaction between Io's atmosphere and Jupiter's magnetosphere produces very complicated distributions of electron density and temperature within Io's ionosphere. The spatial distribution of aurorae depends on the combined distributions of atmospheric density and ionospheric electron density and temperature. None of these properties are currently well known for Io's atmosphere. Observations of auroral morphology may be used to roughly constrain these ionospheric properties. We report time averaged radial profiles of Io's auroral equatorial spot, polar, upstream, and downstream regions obtained with HST/STIS, and scale lengths of brightness above the limb. Simple models of electron density and temperature, neutral atomic atmosphere density, and STIS point-spread-function are used to simulate radial profiles of aurora. These simulated radial profiles are compared with the data to illustrate the utility of these radial scale lengths measured with STIS. This illustration is intended to motivate future comparisons with more detailed Io aurora simulations that realistically model the physics of the plasma-atmosphere interaction, which are needed to better include Galileo spacecraft measurements and constrain the physical properties of Io's ionosphere.

Modelling the Temporal and Azimuthal Variability of the Io Plasma Torus Observed by Cassini UVIS

A. J. Steffl, P. A. Delamere, and F. Bagenal

We present results of our efforts to model the temporal and azimuthal variability of the Io plasma torus during the Cassini encounter with Jupiter. We extend the torus neutral cloud theory model of Delamere et al. (2004) to include azimuthal variations. The temporal variation in torus composition observed by Cassini UVIS can be modelled by supposing a factor of ~3 increase in the amount of material supplied to the extended neutral clouds around Io on 5 September 2000. The 10.07-hour periodicity in the UVIS data and the observed azimuthal variability and modulation can be reproduced by models that assume two independent and azimuthally varying sources hot electrons— one that remains fixed in System III longitude and a second source that slips 12.2 degrees/day relative to System III.

Magnetospheric Radio Emissions from Hot Jupiters

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Scaling laws are derived for high-latitude magnetospheric electromagnetic emissions from the magnetized bodies in our solar system, as a function of the power dissipated in the flow-obstacle interaction leading to these emissions. When extrapolated to “hot Jupiters”, these scaling laws lead to predict intense fluxes, possibly detectable from the Earth. Depending on the magnetization of the planet and of its parent star, the interaction may of stellar wind/magnetosphere type, or involve magnetic reconnection (as in the case Ganymede-Jupiter), or ionosphere/magnetic field "unipolar inductor" interaction (as for Io-Jupiter). Predictions are made for all presently known exoplanets. Detection capabilities and methods are briefly discussed.

SATURN

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Oral Presentations

Wednesday, Thursday, and Friday

-**INVITED-**

Saturn's Radio Emissions

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Saturn's radio spectrum is dominated by cyclotron maser generated emissions at kilometric wavelengths called Saturn kilometric radiation. These emissions range in frequency from as low as a few kHz to as high as 1.2 MHz. They are emitted from high latitudes, primarily in the local morning to noon sector. Surprisingly, given the nearly axisymmetric magnetic field, the emissions are modulated by the planet's rotation, although the radio period has varied from the Voyager-determined value of 10 h, 39 m, 24 s to values as much as 6 minutes longer. A primary challenge of the Cassini mission is to understand this variation so that the true internal rotation period of the planet can be accurately determined. The kilometric radio emissions are also strongly modulated by the solar wind, most notably by the ram pressure. This relation provides valuable diagnostics relevant to magnetospheric dynamics. As is the case at Earth, the Saturn kilometric radiation is evidently generated on field lines threading ultraviolet auroral bright spots and the radiation in these two disparate wavelengths show a general positive correlation. The spectral fine structure of the Saturnian emissions is very similar to that of auroral kilometric radiation at Earth and hectometric and decametric radiation at Jupiter.

Saturn is also the source of relatively weak, narrowband emissions in the frequency range of a few to 10 kHz, thought to be generated by mode conversion of electrostatic waves near the upper hybrid resonance frequency to ordinary mode electromagnetic radiation. A similar generation mechanism is likely also the source of weak, trapped continuum radiation occasionally found in the outer magnetosphere. These two types of emissions are similar to the escaping and trapped continuum radiation at Earth.

-**INVITED-**

X-Ray Emission from the Saturnian System

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In January 2004, Saturn was observed by the Advanced CCD Imaging Spectrometer of the Chandra observatory in two exposures on 20 and 26-27 January; each continuous observation lasted for about one full Saturn rotation. These new observations have detected an X-ray flare from the Saturn's disk in direct response to a solar X-ray flare on January 20, and showed that the Saturnian X-ray emission is highly variable – a factor of 3 variability in brightness over one week. In addition, there is a hint of auroral emission from Saturn's south pole. But unlike Jupiter, X-rays from Saturn's polar region appear to have characteristics similar to those from its disk and they vary in brightness inversely to the FUV aurora observed by the Hubble Space Telescope. These Chandra observations also discovered X-rays from Saturn's rings. The X-ray spectrum of the rings is dominated by emission in a narrow (~100 eV wide) band centred on the atomic oxygen Kα fluorescence line at 0.53 keV. These exciting results obtained from Chandra observations will be presented and their source mechanism will be discussed.

XMM-Newton will be observing X-rays from Saturn in two epochs, each two Saturn rotation long (~21 hr), during 2005 in mid-April and early-November. These observations are planned to take advantage of in-situ observations being conducted by Cassini spacecraft. Preliminary results from the April XMM-Newton observations will also be presented.

-**INVITED-**

Saturn's Aurora: Morphology, Dynamics and Energetics

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The aurora is the most spectacular signature of the electrodynamic coupling between the solar wind, the planet's magnetic field, and its atmosphere. Auroral emissions are the end result of a chain of processes occurring in the planetary magnetospheres and in the upper atmosphere, such as plasma energization, wave-particle interaction, acceleration by electric fields and inelastic collisions of auroral particles with the rarefied gas. We describe recent results obtained with the Hubble Space Telescope, ground-based observations and in situ plasma measurements related to Saturn's aurora. Comparisons with terrestrial counterparts indicate that Saturn's aurora resembles the Earth's case in several aspects but differs in many other ones. Global images of Saturn's south pole FUV auroral emission were obtained in January 2004 and February 2005, concurrent with in situ measurements of the solar wind parameters made on board Cassini. The global morphology was seen to partly co-rotate with the planet. The existence of a favoured longitudinal sector of auroral activity claimed following Voyager FUV spectral and radio measurements will be discussed. Noon intensifications located on or poleward of the main oval are observed, mostly during a minor compression period. Occasionally, the oval displays a spiral structure, or reduces to a bright, concentrated spot. These variations apparently occur as a response to varying solar wind dynamic pressure or IMF. The energy input associated with auroral precipitation is up to several 10^{11} W. It will be compared with the heating rate from solar EUV radiation to estimate the role played by auroral heating on the thermospheric thermal balance.

Open flux estimates in Saturn's magnetosphere during the January 2004 Cassini-HST campaign, and implications for reconnection rates

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During January 2004, HST took a sequence of 68 images of Saturn's southern aurora coordinated for the first time with measurements of the upstream interplanetary conditions made by the Cassini spacecraft. Using the poleward edge of the observed aurora as a proxy for the open-closed field line boundary, the open flux content of the southern polar region has been estimated. It is found to range from ~13 to 50 GWb during this interval; such a large variability providing evidence of a significant interaction with the solar wind. The auroral observations show contractions of the polar cap following solar wind compressions associated with corotating interaction regions and inflations of the polar cap during the high-field regions that follow. These contractions and inflations are due to high nightside and dayside reconnection rates respectively. The upstream solar wind data was used to predict the amount of flux opened by reconnection on the dayside; this prediction then being compared to the observed changes in polar cap area to estimate the amount of flux closed by tail reconnection. Hence, nightside reconnection voltages were calculated and found to peak at ~130 kV in the interval following the 2nd major compression observed during January. There is also evidence of bursty tail reconnection during low-field solar wind rarefaction regions, characterised by nightside voltages of ~30-60 kV.

HST Observations of Saturn's Aurora on 17 Feb. 2005, Coordinated with Cassini Observations of the Night Side Aurora

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New UV observations of Saturn's aurora have been obtained in a campaign on 17 Feb. 2005, using HST to observe the dayside aurora in the southern polar region (presently facing the Earth). Simultaneous observations were obtained by Cassini in an imaging sequence which scanned the UVIS field of view across the northern / nightside polar region. The HST observations were performed with the Advanced Camera for Surveys (ACS) Solar Blind Camera (SBC), a new mode of UV imaging with different properties than the STIS images obtained previously. In this presentation, the scientific goals of this program will be discussed, the HST UV images will be presented and the calibration of the new observing mode discussed. From an initial reduction of the ACS images, the southern aurora were clearly imaged by HST, the emissions appeared on the faint end of the range of brightnesses previously observed, and discrete features were observed rotating at a rate TBD in the direction of the planet's rotation. While it is early in the comparison of the two data sets, any initial scientific results from the comparison of the HST and Cassini data may also be presented.

Cassini Ultraviolet Imaging Spectrograph Observations of Saturn's Auroras

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Cassini's Ultraviolet Imaging Spectrograph (UVIS) has begun making detailed studies of Saturn's auroras. Two long slit spectral channels are used to obtain EUV data from 56.3-118.2 nm and FUV data from 111.5-191.3 nm. 64 spatial pixels along each slit are combined with slit motion to build up spectral images of Saturn, with sufficient spatial resolution to reveal Saturn's auroral oval. Observed emissions include H Lyman-alpha and H2 bands from Saturn's auroras and dayglow. The auroral spectrum is remarkably similar to that of Jupiter, showing short-wavelength FUV absorption due to methane, CH4. Saturn's auroral and dayglow spectra show significant differences. Saturn's aurora is observed to vary in brightness by at least a factor of four. The brightest auroral emissions seen so far occurred after 2004 day 207 19:30 when Cassini CAPS recorded passage of a solar wind shock. The enhanced auroral brightness persisted for days, and is seen at both poles of Saturn. Cassini RPWS observed enhanced auroral kilometric emissions during several auroral brightening events seen by UVIS.

A campaign of Hubble Space Telescope UV imaging with ACS (Advanced Camera for Surveys) of Saturn's dayside southern auroral zone took place on 2005 February 17. Cassini UVIS and VIMS observed Saturn's nightside northern aurora during this period. The UVIS long slit was aligned with lines of latitude on Saturn, providing information about intensity and spectral variations along the auroral oval.

Electron Beams in Saturn's Magnetosphere: Probing Source Regions of its Aurora

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Measurements of the electron pitch angle distributions (PAD) by the LEMMS detector of the Cassini Magnetospheric Imaging Instrument (MIMI) reveal energetic, magnetic field aligned electron beams in parts of Saturn's magnetosphere. Constrained by Cassini's orbital coverage, we discover electron beams in the morning sector of the magnetosphere at radial distances between ~10 to ~25 R_S, as well as in the pre-morning sector between ~20 to ~35 R_S (Saturn radii). We argue that the electron beams are likely to be related to Saturn's auroral features. This would imply that some features of Saturn's aurora map to magnetospheric distances much closer to Saturn than previously assumed. The spatial structuring of the beams is in principle also consistent with the spiral patterns into which Saturn's aurora often evolves.

Linking Saturn's Aurora to Cassini Measurements Using Ground-Based Observations.

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We present measurements of the velocity of ions within the auroral region of Saturn, and link these with in-situ measurements from Cassini, space-based observations from HST, and current magnetospheric and ionospheric models for Saturn.

The Doppler shift velocities show significant sub-corotation across the pole, and we are able to show a number of distinct regions of varying degrees of sub-corotation within the auroral oval. In combining these results with those from other groups, we are able to construct a picture of the effects of the Solar Wind on the Saturnian system, and reveal conditions within both the ionosphere and magnetosphere. As these results come from a long-term Cassini support program, using the CSHELL high-resolution spectrometer on NASA's InfraRed Telescope Facility, we are making significant progress in our understanding of this growing dataset of auroral variability with time and solar wind conditions.

Model of a Variable Radio Period for Saturn

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We propose an explanation for the variations at 1% level of Saturn's radio rotation period measured at kilometer wavelengths. We suggest that non-random variations of solar wind characteristics (especially its velocity) at Saturn may result in systematic displacement of the auroral sources in local time, causing the apparent radio period to be modified or double. We develop two models of local time variations of Saturn's Kilometric Radiation sources and analyze the conditions under which the measured radio period may be shifted by up to a few percent from the planet's sidereal period. Our results provide a possible explanation for the 1% variation observed, and a new interpretation of Voyager observations. We relate the limitation in the accuracy of planetary rotation period determination to long-term variations of "control" parameters (like the solar wind velocity). 1.5-3 years of continuous observations with Cassini will be required for deriving reliably Saturn's true sidereal period.

Saturn's inner magnetosphere

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In the 13 months since Saturn Orbit Insertion (SOI) in July 2004, Cassini has flown within 10 Rs of the planet fourteen times. These passes occurred at different distances and local times, and within a +/- 20 degrees range in latitude, allowing a good three-dimensional mapping of the magnetic field in the inner magnetosphere. We report on our cumulative analysis of all available data, in particular of the vector data from the Fluxgate magnetometer. This analysis provides the first few harmonics of the internal field, and allows disentangling of the planetary magnetic field from that due to external sources. We compare the internal field model with past models based on flyby data. In addition, the current disk, the most important external contribution close to the planet, can be studied and its time evolution monitored. We also look for periodic terms in the magnetic field components, particularly relevant for their role in determining the rotation rate of the inner planet, and in view of recent measurements of the periodicity in the Saturn Kilometric radiation.

-**INVITED-**

Sources of Magnetospheric Neutrals and Plasma

John D. Richardson and S. Jurac
M.I.T.

Voyager measured water group ions and protons in the inner magnetosphere of Saturn but had access to limited regions of the magnetosphere and had limited mass resolution. Cassini has started to provide more detailed information on plasma composition and distribution and on neutral densities. The neutrals and plasma interact and thus these density profiles are not independent. We present results of a model of the neutrals and plasma in Saturn's magnetosphere which self-consistently treats these species. Based on Cassini observations, we are adding a ring source of O_2 to our models. Combining the neutral observations with models of the neutrals and plasma reveals that the source of most of the material is near Enceladus and the peak of the E-ring density. The source is about 10^{28} neutrals s^{-1}, larger than sputtering is able to produce, which may result from collisions of orbital debris. The model predicts peak neutral densities of a few thousand cm^{-3} and a plasma population dominated by molecular ions. We discuss the sources of this material, compare predictions with Cassini observations, and modify the model in light of Cassini where necessary.

Observations of Energetic Ions Upstream from the Saturnian Magnetosphere with Cassini

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The Magnetospheric Imaging Instrument (MIMI) performed comprehensive measurements of the energetic ion population in the environment upstream from the dawn side of the Saturnian Magnetosphere during the approach phase and the subsequent several orbits of the Cassini spacecraft around the planet. High sensitivity observations of energetic ion directional intensities, energy spectra and ion composition were obtained by the Ion and Neutral Camera (INCA) of the MIMI Instrument complement with a geometry factor of ~2.5 cm^2 sr and some capability of separating light (H, He) and heavier (C, N, O) ion groups (henceforth referred to as "hydrogen" and "oxygen" respectively). The observations have revealed the presence of a series of distinct upstream bursts of energetic hydrogen and oxygen ions up to distances of 126 Rs, which exhibit the following characteristics: (1) The hydrogen ion bursts are observed in the energy range ~3 to ~220 keV (and occasionally to E > 220 keV) and the oxygen ion bursts in the energy range ~32 to ~300 keV. (2) The duration of the ion bursts is several minutes up to 4 hrs. (3) The events are of varying composition, with some exhibiting significant fluxes of oxygen. (4) The bursts have a filamentary structure with some exhibiting distinct signatures of "velocity-filtering effects" at the edges of convecting IMF filaments. (5) Some ion bursts are accompanied by distinct diamagnetic field depressions. Furthermore there are indications that the ambient energetic ion fluxes appear to be modulated with the planetary period (11 hrs) at large distances (~800 R_S) from Saturn. Given that energetic ions trapped within the magnetosphere of Saturn are mostly H+ and O+ (Krimigis et al, 2005), we conclude that O+-rich upstream events must be particles leaking from Saturn's magnetosphere under favorable IMF conditions. The observations will be presented and compared to theoretical models.

Reference:

Krimigis et al, Dynamics of Saturn's magnetosphere from MIMI during Cassini's orbital insertion, Science, 307, 1270-1273, 2005.

Plasma Sources and Sinks Observed with the Cassini Plasma Spectrometer

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One of the objectives of the Cassini Plasma Spectrometer investigation is to identify the sources and sinks of plasma in Saturn's magnetosphere. Several methods can be used to identify plasma sources. These include plasma composition and spatial distribution, velocity space distributions, and macroscopic effects such as mass loading. Over the past year in orbit CAPS has observed evidence for plasma sources using all three methods. We have also found evidence for plasma sinks including absorption by Titan's atmosphere and chemical losses in the inner magnetosphere.

The Saturnian Magnetosphere as Revealed by Energetic Particle and Magnetometer Measurements: Cassini Results

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Since July 2004 the Cassini spacecraft has been in orbit around Saturn providing in-situ measurements of the Saturnian magnetosphere. We present energetic particle and magnetic field measurements taken during the first few orbits by the Magnetosphere Imaging Instrument (MIMI) and the magnetometer instrument onboard. In addition to the identification of several magnetospheric regions (radiation belts, plasma sheet, and lobe), we will discuss the structure and dynamics of Saturn's magnetosphere with a special emphasis on the plasma sheet using the results of measured particle intensities, pitch angle distributions, particle energy spectra of ions and electrons as well as magnetic field components. Using the different trajectory geometries of the Cassini orbits, the structure, dimensions, and dynamic behaviour of the plasma sheet and the entire magnetosphere will be described. Possible correlations between energetic particle fluxes and magnetic field anomalies will be discussed as well as reconnection processes in the magnetotail.

A Simple Model of Flows and Currents in Saturn's Polar Ionosphere

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We propose a simple model of the flow and currents in Saturn's polar ionosphere which is motivated by theoretical reasoning, but is quantitatively guided by field and flow data from previous fly-by missions, by more recent data from the Cassini approach phase, and by ground-based IR Doppler measurements. The flow pattern consists of components which are due to plasma sub-corotation in the middle magnetosphere region resulting from plasma pick-up and radial transport from internal sources, and to the Vasyliunas- and Dungey-cycles of convection at higher latitudes. Analytically-expressed representations of these flows are combined with an assumed uniform Pedersen conductivity of the ionosphere to yield patterns of ionospheric Pedersen current, together with the field-aligned current resulting from its divergence. It is shown that a narrow ring of generally upward current surrounds the region of open field lines, which is stronger on the dawn side of the polar cap than at dusk due to the Dungey-cycle flow asymmetry. We associate this current with the 'main oval' auroras at Saturn. Rings of upward and downward current also flow at lower latitudes associated with sub-corotation in the middle magnetosphere. However, the current densities associated with this system are insufficient to require field-aligned acceleration of magnetospheric electrons, so that these currents are not associated with bright auroral ovals, unlike their counterpart at Jupiter.

Global MHD Simulations of Saturn's Magnetosphere: Cassini's First 3 orbits

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We present the results of a 3D global magnetohydrodynamic (MHD) simulation of the magnetosphere of Saturn for segments of Cassini's initial approach to Saturn and its first three orbits through the magnetosphere. We specifically concentrate on times when Cassini is crossing the bow shock and magnetopause and we compare calculated bow shock and magnetopause locations with the Cassini measurements. Preliminary results for Cassini's initial approach show that in order to match the measured locations we must use a substantial mass source due to the icy satellites (~10^{28} water group ions per second). We will present results examining the location and shape of the bow shock and magnetopause during each crossing period and compare them with the results of previous models developed from Voyager data. Again, for the approach period, our preliminary results indicate significant differences from the models of Slavin[1985], with the MHD surfaces being further from Saturn and having smaller flaring angles. Finally, we will present some information about the global configuration of the magnetosphere during these times. For example, we find that the significant tilt of the dipole and Saturn's rotation results in the magnetotail being hinged near Titan's orbit (~20Rs).

Ion Acceleration in Saturn's Magnetosphere—At Least Two Mechanisms, One Possibly Synchronous with Saturn's Rotation, One Analogous to Earth Substorms

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Observations of energetic neutral atoms (ENA) by the Ion and Neutral Camera (INCA) of the Magnetospheric Imaging Instrument(1) (MIMI) reveal two distinctly different regions of ion acceleration with distinctly different characteristics. In the outer magnetosphere in the dawn-midnight quadrant we see evidence of substorm-like activity, apparently driven by solar wind disturbances. In the middle magnetosphere between about 7 and 12 Rs we see repeated acceleration/heating of plasma, along with corotation at close to the planetary rotation period(2). These latter events sometimes appear to be "refreshed" at the corotation period, such that the integrated ENA emission from the inner magnetosphere appears modulated at the rotation period for many consecutive days at a time. We will show examples of these two kinds of events, and speculate on their causes.

1) S. M. Krimigis et. al., Magnetosphere Imaging Instrument (Mimi) on the Cassini Mission to Saturn/Titan Space Sci. Rev., 114/1-4, 233-329, (2004).

2) S. M. Krimigis et al., Dynamics of Saturn's Magnetosphere from MIMI During Cassini's Orbital Insertion Science, Vol 307, Issue 5713, 1270-1273, 25 February 2005 [DOI: 10.1126/science.1106151

Corotating Ion Injections in Saturn's Magnetosphere Observed by INCA: Data-Model Comparison

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Between 16 December 2004 and 6 January 2005 Cassini was almost continuously oriented with the Magnetospheric Imaging Instrument (MIMI) Ion and Neutral Camera (INCA) aimed toward Saturn so it could obtain hydrogen and oxygen energetic neutral atom (ENA) images and follow what seem to be corotating ion injections for several days at a time. The globally-averaged ENA signal strength displays a periodicity which we have interpreted as longitudinally asymmetric, corotating hot ion distributions modified by the Compton-Getting effect: For a sloping ion energy spectrum and a fixed detector energy bandwidth, the flux detected in the direction where the ion distribution moves towards the detector will be higher than the flux detected in the direction where the ion distribution moves away from the detector [Compton and Getting, 1935].

The signal displays several interesting features and differences in hydrogen and oxygen (see Mitchell et al. this meeting). In this presentation we will discuss the results of a simulation of ion injections corotating with the magnetosphere. The model includes protons and O+ drifting in a dipole field with radius-dependent sub-corotation speeds (see Mauk et al. this meeting), and estimates of the charge exchange rate with the ambient neutral gas. ENA images are simulated following the corotation for several days (~9 days) and takes into account the Compton-Getting effect. We use a parametric variation of the neutral gas model by Richardson [1998] (and more recent work by Jurac and Richardson). The simulated ENA images are compared with the INCA H and O ENA images in the ~10-200 keV range.

Magnetosphere-Ionosphere Coupling During Local Plasma Injections at Saturn

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Local (dispersionless) and remote (dispersive) plasma injections appear to be a common feature of Saturn's magnetosphere as seen by the Cassini Plasma Spectrometer (CAPS). CAPS observations of local injections show they occur in "cavities": low density, high-beta plasma regions. Previous work indicates that these observed plasma injections might be consistent with the centrifugal interchange instability, but the detailed role of magnetosphere-ionosphere coupling (via field-aligned currents and Alfven waves) deserves investigation. Using the Cassini magnetometer (MAG) data in conjunction with the observations of CAPS, we study the field aligned currents at the edges of the injection regions (cavities), and the Alfven (or other) waves implied by magnetic perturbations near and inside the cavities.

Global Electron Density Gradients in Saturn's Magnetosphere.

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The Cassini spacecraft has now completed several orbits at Saturn and the Cassini Plasma Spectrometer has successfully measured the distribution of low energy electrons at unprecedented spatial and temporal resolution. Electron density data will be presented from the first eight orbits of the Cassini spacecraft at Saturn. The apoapses are in the morning sector at latitudes within ± 22 degrees of Saturn's equatorial plane. We have adopted two general methods to derive the density of the observed electron populations. The first is from a moment calculation, performed on measurements in the direction which is least affected by spacecraft obscuration, assuming an isotropic electron distribution. The second involves fitting the observed distributions as 1-D shifted Maxwellian distributions. Both these methods are corrected for spacecraft-plasma interactions. We will present results from both methods along with the relative advantages and disadvantages of each and how these must be considered in interpretation of electron data from the Cassini Electron Spectrometer. We find that the density typically decreases with distance from Saturn and will comment on the functional form of this fall off. Well defined boundaries are often observed which appear analogous (for example) to the plasmasphere at the Earth. The Saturn system is revealed to be dynamic with multiple traversals of magnetospheric boundaries during the early orbits. This is likely indicative of a magnetosphere which is contracting and expanding in response to changes in the solar wind.

Equatorial Electron Densities in Saturn's Magnetosphere: Evidence for a Time-Varying Plasma Source in the Inner Magnetosphere

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The Radio and Plasma Wave Science (RPWS) instrument has detected nearly continuous upper hybrid emission bands inside of 10 Saturnian radii for the first seven Cassini orbits. The upper hybrid resonance frequency and the electron cyclotron frequency, derived from the magnetic field measurements of the magnetometer instrument, were used to determine the electron densities with a high degree of accuracy, providing near-continuous electron density profiles for Saturn's inner magnetosphere. The equatorial electron density profiles beyond 5 Saturnian radii for these early orbits show a highly repeatable radial profile varying as $(1/R)^4$. Such a profile is consistent with a magnetic-flux-conserving, source-free, radial outflow of plasma, an outflow that would be expected from a centrifugally driven interchange instability. Inside of 5 Saturnian radii, strong time-dependent deviations occur from the $(1/R)^4$ law. These deviations are indicative of significant time-dependent injections of plasma at radial distances in the range of 3-5 Saturnian radii. Possible sources could include ionization of gas ejected from Saturn's moons, Enceladus and Tethys, and/or evaporation of icy particles in the E Ring.

Cassini CAPS Observations of Saturn's Magnetopause

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Since arriving at Saturn in July 2004 the Cassini spacecraft has made a number of close orbits of Saturn with all the apoapses in the solar wind. As a consequence of the trajectory and the variability of solar wind dynamic pressure the spacecraft has observed multiple crossings of the bow shock and magnetopause. In this presentation we will provide an overview of the magnetopause crossings, all made at low latitudes in the pre-noon dayside magnetosphere from June 2004 to April 2005 as observed by the Cassini Plasma Spectrometer (CAPS). The magnetopause crossings were identified by the change of characteristics of the low energy electron populations. The magnetopause signature in the electron data exhibited varied features at each crossing indicative of different magnetopause configurations. Some crossings are associated with very sharp discontinuities in the electron data, consistent with a closed boundary, while other observations have shown the presence of an interior boundary layer. This latter case suggests an open configuration due to reconnection at the magnetopause. The electron distributions just inside the boundary will be described and we will discuss whether they are of solar wind or magnetospheric origin. The orientation of the magnetopause, as determined by minimum variance analyses of magnetometer data, will be discussed with reference to the accuracy of existing boundary models and the presence of boundary waves. Other observations such as the presence of a Plasma Depletion Layer and a search for Flux Transfer Events will be described

-**INVITED-**

Titan's Magnetospheric Interaction: Status After Cassini Titan Close Encounters TA,TB,T3,T4,T5

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Progress in the understanding of Titan's magnetospheric interaction is due to new data from the Cassini mission and new 3D-modelling results,where we emphazise the magnetic field data in this overview . In detail the following new sources of physical information are now available:

1. The Cassini encounters TA, TB, T3 allow the study of magnetic tail and wake formation in comparison with the Voyager-1 encounter for magnetospheric conditions near Saturnian local noon. The observations can be explained in terms of the draping picture already applied to Venus, Mars and comets in the solar wind in the past. The symmetries in the latter cases where the plasma flow and solar photon energy flow is coming from the same direction is broken in the case of Titan in the most pronounced way near Saturnian local noon(and midnight).This leads to a strong asymmetry in the tail of the induced magnetosphere connected to day and night. In all three cases the flybys occurred well inside the magnetosphere without any evidence for a bow shock as expected for sub-fast flow conditions. The transition in polarity of the draped field is complex. Another transition layer between the draped Saturnian magnetic field and the low field lower ionosphere called the magnetic ionopause could be studied during TA and TB. The good agreement between advanced 3D-models of the interaction and observations indicates the already good understanding of the general picture.

2. Advanced 3D-fluid models and kinetic models have been developed and are being developed for comparison with Cassini data. The good agreement between the predictions of the model by Backes (2004;Science,2005)and observations suggests the importance of the model features as the detailed description of ionospheric dynamics and the electron energy budget involving heat flow along the highly distorted field lines.

3.The encounters T4 and T5 will provide interesting new information on the interaction under Saturnian local dawn conditions also including the closest flyby to date at 1025 km altitude of closest approach(T5).

4.A first assessment of the internal magnetic field problem is possible from the TB and T5-data.This is complicated by the possible presence of electromagnetically induced and dynamo fields of internal origin. We shall discuss selected topics from the general problem area using published and new magnetic field data but also published results from other particles-and-fields Cassini experiments as well as the improved theoretical understanding.

-**INVITED**-

Composition of Icy Objects in the Saturn System as Seen by Cassini VIMS

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The Cassini Visual and Infrared Mapping Spectrometer (VIMS) is an imaging spectrometer on the Cassini spacecraft that covers the spectral range of 0.35-5.2 um in 352 spectral channels, a nominal instantaneous field of view of 0.5 mrad and an image format of 64x64 pixels. During the several months in orbit around Saturn VIMS has at the time of writing made extensive observations of Saturn's rings, its icy satellites, in particular Phoebe and Iapetus, and had 1 distant and 3 close flybys of Titan.

Results for the flyby of Phoebe show that it's surface is dominated by water ice and bound water, but it has significant amounts of ferrous-iron-bearing silicates, CO_2 as liquid or gaseous inclusions in minerals, organics, CN compounds and several as yet unidentified compounds. Phoebe's surface composition is consistent with other outer solar system objects.

Results for Iapetus show the presence of water ice, bound water, CO_2 complexed in a similar fashion as on Phoebe, organics and several as yet unidentified surface components.

Results for Enceladus show a surface that is almost pure water, with no detectable nonwater molecular components. Some variations in the size of the individual water-ice grains is seen.

Saturn's rings are seen by VIMS to be composed of almost pure water ice with small amounts of contamination/coloration that seem to be more abundant in the inner portion of Saturn's rings and in the ring gaps. VIMS has detected radial structure in the composition of Saturn's rings all the way down to the roughly 20-km resolution limit of the data obtained during Saturn Orbit Insertion (SOI).

Titan's Ionosphere: Model Comparisons with Cassini Data

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The first in situ measurements of the main part of Titan's ionosphere were made during the October 26, 2004 Ta encounter of the Cassini Orbiter with Titan by the Langmuir Probe part of the Cassini Radio and Plasma Wave Experiment (RPWS). The Cassini Ion and Neutral Mass Spectrometer (INMS) made the first in situ measurements of Titan's neutral atmosphere during this encounter. The INMS measured both the neutral and ion composition of the upper atmosphere during the T5 encounter. This paper presents model calculations of Titan's ionosphere for conditions appropriate for the Ta and T5 encounters. The model results are compared with Cassini data. During the Ta encounter the Cassini Orbiter moved from the dayside to the nightside with a closest approach altitude of 1174 km. In order to obtain agreement between measured and calculated electron densities the model needs to include ionization due to both solar radiation and energetic electrons from Saturn's magnetosphere. Model-data comparisons for the T5 encounter will also be presented.

The Global Plasma Environment of Titan as Observed by Cassini Plasma Spectrometer During the First Two Close Encounters With Titan

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The Cassini spacecraft flew by Titan on October 26, 2004 and December 13, 2004. In both cases it entered the ionosphere of Titan, allowing exploration of its plasma environment. Using observations from the Cassini Plasma Spectrometer (CAPS) we examine Titan's global plasma environment. On both occasions CAPS detected plasma populations distinct from those of the Kronian magnetosphere at about 1-1.5 Saturn radii from the moon. Closer to Titan CAPS observed drifting ion ring distributions originating from Titan and, in addition, a corotating flow that was significantly decelerated around the moon due to mass loading. Near the moon, but above the ionosphere, very cold plasma was dominant.

In this presentation we shall characterize the plasma in detail in the different regions: we attempt to clarify what type of ion distributions (beam/shell/ring) we observe; what are the dominant ion species; what sources can be identified; and how the ion pickup processes could be explained around Titan.

We also compare the plasma environment of Titan to those of other nonmagnetic solar system bodies.

The Nature of the Plasma Density Enhancements near Titan

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At the time of the Voyager 1 close encounter with Titan, enhancements of density and sharp decreases of electron temperature were observed by the PLS instrument. These were interpreted by Eviatar et al.(1982, JGR, 87, 8091) as plumes drawn out of the ionosphere of Titan by the corotation electric field. A few weaker enhancements were identified inside and outside Titan orbit and their displacements correlated with variations in solar wind dynamic pressure observed by Voyager PLS one and two corotation periods earlier. The subplumes were interpreted to be the remnants of plasma drawn out earlier and the rate of decay was associated with the assimilation of the plume into the ambient plasma. This model was disputed by Goertz (GRL, 1983, 10, 455) who viewed them as blobs of plasmas detached by centrifugal force from the central body of Saturn plasma in the inner magnetosphere. The Voyager PLS instrument was unable to make a firm composition determination which would have resolved the question, although Hartle et al. (JGR, 1982, 87, 1383) did identify an ion of mass to charge ratio 28 in the near-Titan plasma. As of the writing of this abstract, no 'smoking gun' indicating clearly a Titan or inner magnetosphere composition of the enhanced plasma regions has been found. In view of the location of Titan orbit outside the 'plasmapause' it may well be that the primary plume coming out of Titan cannot complete a full circuit of the magnetosphere and is swept down the tail as predicted for all magnetized planets by Vasyliunas (Physics of the Jovian magnetosphere, ed. Dessler, 1983). In this case, the analysis of Goertz may well prove to be the more realistic although the correlation of the radial positions of the enhancements seen near Titan with magnetopause motion yet remains to be explained.

What Drives Titan's Upper Atmosphere?

I. C. F. Mueller-Wodarg, R. V. Yelle, M. Galand, N. Borggren, J. H. Waite and the INMS Science Team

Titan's upper atmosphere, its thermosphere and ionosphere, form an extended layer of neutral and charged particles reaching out to more than half a Titan radius into space from the surface of Saturn's largest moon. The principal neutral gases, nitrogen and methane, absorb solar EUV radiation, which drives extensive ion and neutral photochemistry and provides an important external source of energy. Recent observations by Cassini's Ion Neutral Mass Spectrometer (INMS) and other instruments have found extensive waves and horizontal structures in temperatures and methane abundances which suggest the presence of important coupling processes to the lower atmosphere as well as to Saturn's ambient magnetosphere. First measurements were also obtained of Titan's ionospheric properties. By comparing observations from different Cassini-Titan encounters and presenting accompanying numerical simulations we will assess the processes that drive dynamics, energetics and chemistry in Titan's upper atmosphere.

Molecular Oxygen Ions in the Vicinity of Saturn's F and G Rings

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During Saturn orbit insertion on July 1, 2004, Cassini passed over the B, A, and F rings and the Cassini division before descending, inside the G ring, through the ring plane. The ion mass spectrometer (IMS), a component of the Cassini plasma spectrometer (CAPS), observed enhanced ion flux during this ring plane crossing whenever the instrument viewing was into the co-rotation direction. Analysis of the IMS data obtained over the main rings indicates the presence of both O+ and O2+, likely produced by UV photosputtering of the icy rings and subsequent photoionization of O2 (Young et al., 2005; Tokar et al.,2005; Johnson et al., 2005). In addition, Tokar et al. (2005) reported the first detection of O2+ in the thermal plasma just outside the main rings, in the vicinity of the F ring. In this contribution, we focus on the IMS data obtained between the F and G rings with particular emphasis placed on the O2+ concentration and the consistency with the Richardson and Jurac (2004) thermal plasma model.

Cassini's First Titan Encounters: Plasma Results

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We compare plasma data from the first encounters of Titan by the Cassini-Huygens mission. Several features in the ionosphere appear to be present at every encounter, including ionospheric photoelectrons. Other features in the larger scale interaction are different between encounters, such as the interaction size, detailed structure, geometry and the magnetospheric conditions in which Titan is immersed. A surprising observation during at least one encounter is that of heavy negative ions. In this paper we will compare the electron and ion measurements made by CAPS and explore possible reasons for the difference in the observed structures at the different encounters.

Cassini Magnetometer Observations from Enceladus

Michele K. Dougherty, K. K. Khurana, C. T. Russell and F. N. Neubauer

Cassini magnetometer observations from the three recent flybys of Enceladus will be described. The magnetic field observations reveal a clear bending of Saturn's field lines around the moon with the magnetospheric plasma being slowed and deflected. In addition water group ion cyclotron waves arise in the vicinity of the moon. These observations are consistent with strong plasma loading occurring in a broad region around Enceladus. Implications of the observations will be discussed as well as initial modelling work which has been carried out in order to describe the observations.

Icy Satellite Microsignatures Observed by Cassini/MIMI During its First Orbits of Saturn

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(1)JHU/APL
(2) APL
(3) Max Planck Lindau
(4) APL
(5) SWRI
(6) MSSL
(7) Fundamental Technologies

The Cassini spacecraft has now completed several orbits of the planet Saturn. Data from the Magnetosphere Imaging Instrument (MIMI) have revealed signatures of the icy satellites through decreases in ion and electron count rates at or near their orbital distances. These decreases correspond to extended wakes both up and downstream of the satellite in the flowing plasma. Above a cutoff energy, electrons drift in the direction opposite to the plasma flow and therefore the region depleted of these particles is upstream of the satellite. Preliminary studies reveal very deep depletions of electrons due to the efficient absorption of these particles by the satellites. At times when the spacecraft crosses satellite orbits longitudinally distant from the moons, we observe that the initial decreases have partially filled in; wakes may also be displaced radially from the orbit of the satellite. Preliminary analysis suggests that this radial displacement may depend on energy in some cases. In this presentation, we will summarize the observations and analyze the evolution of these wake features. This analysis will include the fill in of the initial signature as well as the radial diffusion of the wake and its energy dependence. Finally because these features can have very specific manifestations, we will discuss some implications of these signatures on our analysis of detector-penetrating particles.

Molecular Oxygen Ions Within Saturn's Inner Magnetosphere as Observed by Cassini: Initial Results

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(4) Los Alamos National Laboratory, NM
(5) Southwest Research Institute, San Antonio, TX

We will present initial results of our analysis of molecular oxygen ions within Saturn's inner magnetosphere as observed by the Cassini Plasma Spectrometer (CAPS) experiment. As reported in Young et al. (2005) the O2+ is a minor species in the magnetosphere, but is dominant over the main rings (Tokar et al., 2005). This analysis, confined outside Mimas' L shell, will be built around the work of Sittler et al. (2005) who computed fluid parameters of protons and water group ions within Saturn's inner plasmasphere. A non-linear analysis of the composition data will be used. We will constrain the analysis by requiring the O2+ to be comoving with the water group ions. This will allow us to make estimates of ion density and temperature for the O2+ along the various Cassini trajectories through Saturn's inner magnetosphere. Molecular oxygen is important because it can be produced by gas phase processes, but can also be a signature of the decomposition of icy surfaces by radiolysis and photolysis (Johnson et al 2003; 2004). Therefore, similar to the observation of an ozone-like feature on Dione and Rhea (Noll et al. 1997), the observation of molecular oxygen ions can be a marker for the radiation-induced erosion of ice grains and icy bodies within Saturn's magnetosphere. Our results will examine the formation and redistribution of molecular oxygen within the inner magnetosphere.

Nitrogen in Saturn's Inner Magnetosphere

H.T. Smith(1), M. Shappirio(2), E.C. Sittler(2), D. Reisenfeld(3), R.E. Johnson(1), R.A. Baragiola(1), F. J. Crary(4), D.J. McComas(4), D. T. Young(4)
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The detection of low energy N+ in Saturn's inner magnetosphere (3.5 < L < 9.5) by the Cassini Plasma Spectrometer (CAPS) is the first evidence for the presence of neutral nitrogen that is locally ionized in this region. This detection was accomplished using CAPS data for the first six orbits. Voyager's detection of unresolved mass/charge 14-16 amu/e ions in this region caused much debate over the possible presence of N+ in Saturn's magnetosphere. Two principal nitrogen sources have been suggested: material from Titan's atmosphere and nitrogen compounds trapped in the icy satellite and ring particle surfaces (e.g., Sittler et al 2004a, b; Smith et al. 2004). The latter may contain primordial nitrogen, likely as NH_3 in ice (Stevenson 1982; Squyers et al. 1983) or nitrogen that has been implanted in the surface (Delitsky and Lane 2002). Here we present results supporting N+ detection and show that the immediate nitrogen source is likely to be the icy satellites (Young et al. 2005; Smith et al. 2005a). The strongest spatial correlation of N+ is with Enceladus (Smith et al. 2005b).

Possible Mechanisms for Local Plasma Injections in Saturn's Magnetosphere

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Our previous work on local plasma injections in the inner Saturn magnetosphere showed that they obey the general predictions of centrifugal interchange. However, issues such as the radial distance to the source regions, the inward transport velocities of the events, and the possible importance of non-adiabatic acceleration processes remained unanswered. This paper will report on further investigations of these phenomena using data from the Cassini Plasma Spectrometer and Magnetometer.

RPWS Cold Plasma Results from the Inner Magnetosphere of Saturn

J.-E. Wahlund (1) , R. Boström (1), A. I. Eriksson (1), G. Gustafsson (1), D. A. Gurnett (2), W. S. Kurth (2), P. Canu (3), T. F. Averkamp (2), G. B. Hospodarsky (2),A. M. Persoon (2), M. Desch (4), F. M. Neubauer (5), M. K. Dougherty (6), M. W.Morooka (1), R. Gill (1), M. André (1), and I. Mueller-Wodarg (6)
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(3) CETP/CNRS/IPSL, Velizy, France
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(5) Institute for Geophysics and Meteorology, Köln University, Germany
(6) The Blacket Laboratory, Imperial College London, UK

We present new results indicating that ring-dust is a major plasma source for the magnetosphere of Saturn. This study of the cold plasma near the ring plane of Saturn is based on observations by the Radio and Plasma Wave Science (RPWS) instruments on board the Cassini spacecraft. A dense dust-ring plasma was detected both during the inbound and outbound crossings of the ring plane. The Langmuir probe and plasma emission measurements revealed an increase of the plasma density up to 100 cm-3, and the dense plasma was centred around the maximum count rate of impacting micrometer sized dust particles on the spacecraft. Furthermore the Langmuir probe observations pointed toward a cold plasma population with T e~0.5 eV near the ring plane which increased to several eV farther from the ring plane. The ram current to the spherical probe indicated an average ion mass between 20-40 amu, which was confirmed by the INMS instrument, which showed that the dominating ion here was O2+. The plasma density decreased to very low values when Cassini passed over(northward) the visible rings of Saturn, which suggest that the ring-plasma is most dense just outside the F ring. The visible rings presumably absorb magnetically mirrored charged particles on conjugate magnetic field lines, and hence the plasma density is low inside the F-ring. Cold plasma from the icy moons and/or plasma sphere (co-rotating) was also detected by RPWS. At least the cold plasma torus of Dione is confirmed, as was indicated from earlier Pioneer and Voyager measurements. The analysis of the observations is in process and the results are preliminary. Electron temperatures of several eV and a lighter ion composition(presumably water group ions) are indicated. Except during the Saturn Orbit Injection(SOI) spacecraft burn, the spacecraft potential was determined above the rings and elsewhere in the magnetosphere of Saturn. From the information of the thermal plasma and the spacecraft potential we will make an attempt to infer the electric charge of dust particles. For instance, the E-ring particles could be a few Volts negative.

Towards a Mapmaking of the Electron Temperature and Density in the Inner Magnetosphere of Saturn.

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As has been done successfully during the SOI of Cassini (1 July 2004), we plan to measure in situ the electron temperature and density at each perikrone of Cassini using the electric dipole antenna of RPWS, with the technique of Quasi Thermal Noise spectroscopy.
We review the basics, the advantages and the limitations of the technique. Then we show plasma measurements acquired in the inner magnetosphere of Saturn (2.3 - 6 Rs, mainly within the E ring), during the SOI and around the perikrones of 9 March 2005 (at 3.5 Rs) and of 14 April 2005 (at 2.6 Rs). Finally, we discuss these results in terms of confinement of the kronian plasma torus and we compare it with the Io torus case.

COMPARATIVE MAGNETOSPHERES

Oral Presentations

Friday

-**INVITED-**

Solar wind-magnetosphere-ionosphere interactions at Jupiter and Saturn

Stanley W H Cowley
Department of Physics & Astronomy, University of Leicester, United Kingdom

An overview will be given of recent work on large-scale aspects of solar wind-magnetosphere-ionosphere coupling at Jupiter and Saturn, focussing particularly on the coupling currents generated and their relationship with the observed auroras. Recent theoretical modelling work will be reviewed, and discussed in relationship with plasma, field, and auroral observations.

-**INVITED-**

Rotationally-Driven Dynamics in the Magnetospheres of Jupiter and Saturn

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Cassini observations at Saturn have revealed a rotationally-driven magnetosphere that is quite analogous to the larger, more powerful magnetosphere of Jupiter. Saturn's magnetosphere is not, except in physical size, ''intermediate" between the magnetospheres of Earth and Jupiter, as is sometimes said. It is simply a smaller, less powerful version of Jupiter's magnetosphere. Both are rotationally driven; the magnetospheric plasma flow is dominated by the partial corotation imposed by the planet, not by the Sun-aligned convection system imposed by the solar wind. Both are populated predominantly by heavy-ion plasma deriving from sources deep within the magnetosphere (Io and perhaps Europa in Jupiter's magnetosphere; icy satellites and rings in Saturn's). The rotational energy source and the internal mass source are not independent: the internal mass source is essential to tapping the planetary rotational energy to drive magnetospheric processes. In both cases (Jupiter and Saturn), plasma from the internal sources is transported outward through a centrifugally-driven interchange (convection) process comprising alternating azimuthal sectors of mass-loaded outflow and mass-depleted inflow. This interchange process, although much more vigorous at Jupiter, is more readily observed at Saturn because of its much weaker magnetic field. The weaker field implies faster gradient and curvature drift speeds at a given distance for a given particle energy. The resultant drift dispersion signatures, which are diagnostic of the radial transport process, are thus much more apparent at Saturn than at Jupiter. Analysis of these dispersion signatures, as observed by the Cassini Plasma Spectrometer, provides unique constraints on the underlying interchange transport process.

-**INVITED-**

Magnetospheric Plasma Composition at Jupiter and Saturn

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Southwest Research Institute

The composition of Jupiter's and Saturn's magnetospheres provide information on sources and sinks of plasma, transport rates, magnetospheric dynamics and circulation. At Jupiter, the plasma is primarily composed of sulphur and oxygen ions from Io and Io's neutral clouds. In Saturn's magnetosphere, the plasma originates from the icy satellites and ring and is composed of hydrogen and water group ions. In the case of both Jupiter and Saturn, additional minor species provide additional information on the transport of material from one region of the magnetosphere to another. This presentation will review the various measurements of composition (spectroscopic remote sensing, analysis of energy spectra from plasma instruments, mass spectroscopy and measurements of ion cyclotron waves), summarize how these data have been used to understand the magnetosphere of Jupiter, and describe ways they may be used to understand the magnetosphere of Saturn.

The Global Kronian, Jovian, and Terrestrial Magnetospheric Magnetic Fields: Compared and Contrasted

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The planetary internal field, plasma processes inside the magnetosphere, and the interaction of these with the solar wind all contribute to determining the structure of the global magnetospheric magnetic field. The properties of the solar wind vary greatly from Mercury to the outer solar system and so one would expect a steady variation in solar wind interactions through the solar system. However, not only do solar wind properties vary, but the planetary internal field strength, tilt and offset vary along with the nature and degree of mass-loading and the type of solar-wind interaction.

Nevertheless, we can learn much from the structure of the global magnetospheric magnetic field by comparing and contrasting between different magnetospheres. Cassini has now accumulated sufficient orbits to start to examine the global magnetic field of Saturn, search for asymmetries, and make more comprehensive initial comparisons with other magnetospheres.

Using magnetometer data from the first ten orbits of Cassini we study the global field, with the planetary internal field removed to reveal the effects of mass-loading, current systems, and the solar wind interaction. These data are compared and contrasted with the structure of the jovian and terrestrial fields and also with global models of the magnetospheric magnetic field. We comment on the morphology of the plasma sheet and how the observed morphology compares to Jupiter. We examine the structure in the magnetic field near current sheet crossings and comment on the mass of the magnetodisc and the mass outflow through the plasma sheet relating this to the global field.

Mass Loading, Fast Neutral Production and Ion Cyclotron Waves in the Magnetospheres of Jupiter and Saturn

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When an atmosphere is sufficiently thin, it cannot support an ionosphere with sufficient pressure to stand off the flow of the solar wind or corotating magnetosphere in which that body resides. In this situation the flowing plasma has access deep into the atmosphere and any slowing or deflection of the plasma flow is a product of the mass loading process, in which new ions are incorporated in the flow, and not due to a magnetic barrier draped over a highly electrically conducting ionosphere. The jovian magnetospheric plasma runs into Io at a relative velocity of 57 km/sec with a density of about 2000 sulphur and oxygen ions per cm^3 and picks up about 1000 kg/s of mainly SO2+ and SO+ ions. This addition of mass and its subsequent acceleration to the corotation velocity draws energy from the rotation of the planet through a field-aligned current system extending into the ionosphere and closing on pressure gradients in the magnetosphere. Most surprisingly, the region of mass loading extends far from Io as marked by the domain of ion cyclotron wave generation. Fast neutrals are created at Io and transport some of the ton per sec of new material across field lines far from Io. Ultimately outward transport powered by this centrifugal force due to Io's mass loading deposits the ions in the tail, maintaining a steady state ion population.

A similar process occurs in the Saturnian magnetosphere at both Enceladus and throughout the E ring. However, at Saturn the working molecule is H_2O and water group ion cyclotron waves are observed throughout the equatorial magnetosphere from 4 to 6 Saturn radii. We estimate that the rate of mass addition is about one order of magnitude less than in the jovian magnetosphere, and that this material is sufficient to drive a jovian type circulation system, but at a slower outflow speed. Thus it appears that, despite the dissimilarity of the Galilean moons and their Saturnian counterparts, the basic driving forces in the two magnetospheres have much in common.

Observations of Saturn's Ring Current and Comparisons with Earth and Jupiter

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The Charge-Energy-Mass Spectrometer (CHEMS), one of three sensors comprising the MIMI investigation on Cassini, measures the mass and charge state of ions in the energy per charge range 3-220 keV/e. This energy range includes that of Earth's ring current and apparently also that of Saturn's ring current. We have examined data from Cassini's first five passes through the magnetosphere. A persistent ion population was observed in the L=6.3-11 range that presumably comprises Saturn's ring current. Protons, singly charged oxygen, and molecular hydrogen ions predominate. Other water products are present. The spectra of the different species are nearly parallel power laws in the lower portion of the CHEMS energy range. Breaks in the spectra occur above 50 keV to 100 keV depending on the orbit, but at the same energy for all species. In general the intensities at the lower energies decrease with decreasing radius over this radial range (to nearly zero at the 6.3 Rs orbit of Dione), probably due to loss by charge exchange with the neutral gas in the region. At higher energies the effects of energization by inward radial diffusion are observed.

We will discuss the energy content and composition of Saturn's ring current and its variability and compare these observations with those at Earth and Jupiter, including measurements made by CHEMS during Cassini's Earth flyby.

Local Stability Criterion for Quasi-Interchange Modes in Giant Planet Magnetospheres

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In order to investigate the interchange instability rigorously and to gain new insights into its role in plasma transport in giant planets magnetospheres, we have derived its local stability criterion for nonuniform, gyrotropic, and multicomponent plasmas representative of the Jovian and Saturnian magnetospheres. The obtained criterion is specifically designed for interpretations of the observational data provided by the Galileo and Cassini missions.

Galileo measurements gave hints of the small-scale transport of plasma by flux tube interchange motions in the magnetosphere of Jupiter, in particular in the highly structured Io plasma torus surrounding the planet. Cassini measurements identified convective motions expected to result from the centrifugal interchange instability in the inner corotation-dominated regions of the magnetosphere of Saturn.

Motivated by these observational evidences, we apply our theoretical findings to realistic plasma and field distributions in these environments, based on the most recent available observational data, with the aim of checking whether these distributions are stable or unstable against interchange motions.

SATURN

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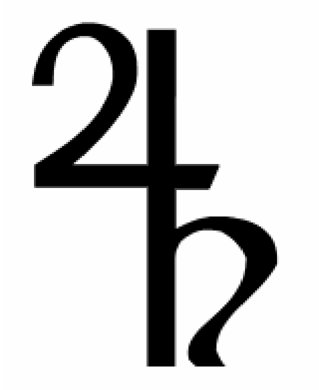
and

COMPARATIVE MAGNETOSPHERES



Posters

Wednesday, Thursday, and Friday

Azimuthal Field Signatures in Saturn's Magnetosphere: Radial Currents and Dynamics

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We examine magnetic data acquired by the Cassini magnetometer (MAG) during the spacecraft's excursions into Saturn's magnetospheric lobes, as well as the planet's disc-like middle magnetosphere (the latter at distances of 8-15 R_S in the equatorial plane). Since the planet's internal field is nearly axisymmetric, a comparison of the azimuthal field component in these two regions allows us to isolate magnetic sources which are due to external current systems and magnetospheric dynamics.

We find very different physical mechanisms and magnetic structures in these two regions. The lobe regions are magnetically dominated by magnetopause currents, which vary with the response of Saturn's magnetosphere to external drivers, especially the variability of physical conditions in the solar wind. We use a new field model for Saturn's magnetosphere to estimate the strength of these magnetopause currents. The middle magnetosphere, on the other hand, has an azimuthal field structure dominated by radial currents which flow in response to coupling with the ionosphere. We compute the variation of these currents as a function of radial distance, and comment on some implications for kronian magnetospheric dynamics, drawing a preliminary comparison and contrast with the jovian system.

An Initial Assessment of Stress Balance in Saturn's Magnetosphere From Cassini

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Empirical models of magnetospheric magnetic fields are ubiquitous in space physics and are used in many applications, from mapping field lines to removing background fields. These models are fitted to large databases of magnetometer observations, and in some cases are well parameterised with respect to upstream conditions, however they are still large-scale time-averaged models. By construction they are good representations of the global magnetic field however they largely ignore the plasma conditions. For many applications this is entirely reasonable but in some cases one must exercise care, especially in applications where plasma gradients have a large effect such as in the formation of field-aligned current systems. Thus it is instructive to examine whether these models are in force balance with the plasma.

Connerney et al. (1983) examined the stress balance implicit in their magnetodisc model of Saturn's ring current under the assumption of isotropic pressure. We extend this analysis by examining the curl and curl-free parts of the jxB force, as evaluated from several models of Saturn's global field [Connerney et al. 1983; Giampieri and Dougherty 2004; Arridge et al. 2005; Khurana et al. 2005] and thus investigate the relative roles of pressure gradient, centrifugal, and pressure anisotropic stresses in Saturn's magnetosphere, in both the noon and dawn local-time meridians. Our results are compared and contrasted with stress balance investigations in the terrestrial magnetosphere [Spence et al. 1987; Horton et al. 1993; Cao and Lee 1994; Zaharia and Cheng 2003] and at the outer planets [McNutt 1983; Vasyliunas 1983; Mauk et al. 1985, 1987; Caudal et al. 1986].

Our results are compared with direct estimations of the jxB force from the magnetic field data in the vicinity of the current sheet. We also compare our results with observed plasma populations [Sittler et al. 1983; Lazarus and McNutt 1983; Young et al. 2005], discuss the physical driving mechanisms, and comment on the stability with respect to MHD instabilities.

Recent Progress in Modelling Saturn's Global Magnetospheric Magnetic Field and Current Distributions

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We present recent progress in the development of a flexible global magnetospheric magnetic field model, based on techniques used by modellers of the terrestrial magnetosphere. The equatorial current sheet is modelled using the axisymmetric models of Tsyganenko and Peredo (1994), which are tilted and hinged to non-equinox dipole tilt angles using the general deformation method [Tsyganenko 1998]. To generate a global model we shield the current sheet field and the internal field of the planet inside the magnetopause using cartesian and cylindrical harmonic scalar potentials respectively. We also introduce modules which model the field of the radial current, enforcing (partial) corotation through the magnetosphere, and an interconnection field to generate an open magnetospheric model.

The advantage of the Tsyganeko and Peredo current disc models is that we can superpose multiple current sheet 'modes' with different current maxima and radial gradients, in order to more accurately represent the observed magnetic field, and hence the underlying current distribution. Because of the near axisymmetry of Saturn's internal magnetic field, Cassini does not experience diurnal changes caused by the motion of the current sheet with respect to the observer. Consequently our knowledge of the true current distribution is limited. By the careful selection of current sheet modes we can assess the current distribution through magnetic field modelling. This not only improves our magnetic field models but also our understanding of kronian current systems and the underlying physics.

We compare the model field with observations from both Voyager and Cassini and present our understanding of the equatorial current distribution as derived through our model.

Characteristics of the Saturnian Bow Shock Crossings as Measured by CAPS

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In this study we analyse the upstream and downstream regions of the Saturnian bow shock so far encountered by the Cassini spacecraft since the Saturn Orbit Insertion. We use CAPS-IBS, IMS-SNG and IMS-TOF measurements together with the Magnetometer data. We concentrate on identifying certain plasma regions characterized by different ion distributions in the vicinity of the bow shock and by determining the obliquity and the strength of the shock we estimate its kinetic effects on the plasma particles. Since so far the onboard instruments of Cassini only registered multiple bow shock crossings at Saturn, we suggest a dynamic shock front, and looking at it from both global and local points of view we compare it with the bow shocks of other planets so far visited by spacecraft in order to establish basic similarities between them.

IMF and Saturnian Aurora

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Difference in the solar wind interaction with magnetosphere for Saturn relative to the Earth, in particular, results from the decrease in the solar wind plasma density and magnetic field strength, and from the change in average angle of the IMF. Other reasons are Saturn's rapid rotation and internal magnetospheric plasma sources. The observed by Cassini IMF structure at the heliocentric distances ~5-9 AU is consistent with corotating interaction regions (CIRs) existing during the declining phase of the solar cycle. Two unusual cases on 18 and 26 January 2004 are considered when disturbances in the solar wind passed Saturn. After the solar wind shock encountered the kronian magnetosphere, the auroral oval became brighter (especially at dawn) with a reduced radius. In these cases the auroral power was anti-correlated with the radius of the oval. It was shown that such unexpected behaviour could be caused by the suggested mechanism: arising of the Saturnian transition current system (as at Earth under corresponding conditions). In both of these events, IMF at the shock turned southward from the near horizontal orientation, and the effect of the southward solar wind magnetic field on the polar cap area occurred to be stronger than the effect of the sharply increased dynamic pressure.

In Situ Observations of a Solar Wind Compression-Induced Hot Plasma Injection in Saturn's Tail

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During the Saturn orbit insertion (SOI) fly-through of the Cassini spacecraft, Saturn's magnetosphere underwent a significant corotating interaction region (CIR) related compression. Such compressions have recently been suggested to produce rapid bursts of tail reconnection, enhanced Saturn kilometric radiation (SKR), and consequent auroral dynamics. On the outbound pass the spacecraft became engulfed by hot plasma, associated with a reduction in field strength, and a change in orientation indicative of a dipolarisation. Concurrently, a substantial enhancement in SKR emissions took place, together with a disruption of the typical planetary modulation. We suggest this is the first in situ evidence of compression-related tail collapse via magnetic reconnection and hot plasma acceleration in Saturn's magnetotail.

SKR Localization, Polarization and Flux Measurements with the Cassini/RPWS Instrument

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(2) LESIA, Observatoire de Paris, Meudon, France

The Cassini spacecraft arrived at Saturn in July 2004, beginning a 4-year period of observation of the kronian system. The Radio and Plasma Wave Science experiment (RPWS) is dedicated to the study of the electromagnetic phenomena that can be observed there. The High Frequency Receiver (HFR) of the RPWS experiment has so-called direction-finding (DF) capabilities, i.e. one can retrieve quasi-instantaneously the direction of arrival of an incoming wave, its polarization state and its flux. We use these DF capabilities to characterize the source position, polarization state and flux of the main kronian radio emission: the SKR (Saturnian Kilometric Radiation). The radio occultations induced by the Titan flybys have also been used to check and complete the study.

Variations of Jovian and Saturnian Auroras Induced by Changes of Solar Wind Dynamic Pressure

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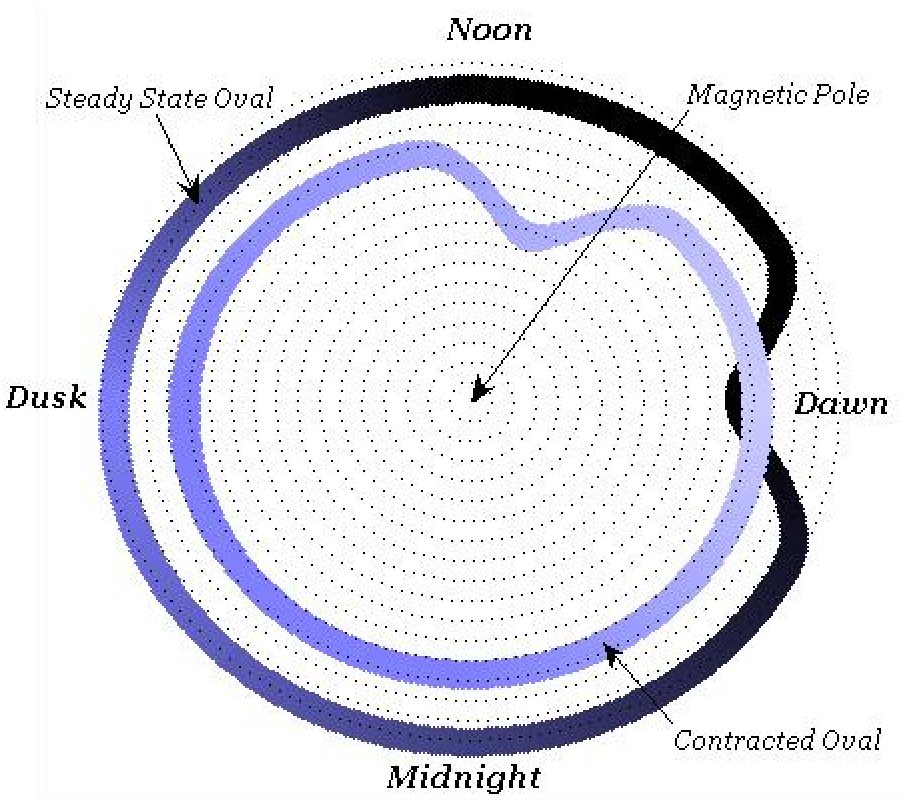
The jovian and saturnian auroras include persistent “main” ovals that encircle each magnetic pole and are apparently associated with the upward field-aligned part of the corotation enforcement current system. Recent theoretical studies have suggested that the main ovals should temporarily dim after the arrival of a solar wind shock wave, because the sudden compression of the magnetosphere reduces the difference between the rotation rates of the magnetosphere and the planet. Recent observations of Jupiter and Saturn have revealed the opposite effect: the auroral oval brightens, and moves poleward, after the arrival of a solar wind shock. We attribute this discrepancy to the flywheel effect of the neutral atmosphere in the Pedersen-conducting layer. We find that a large and sudden magnetospheric compression can produce a temporary reversal of the polarity, and a simultaneous increase of the intensity, of the corotation enforcement current system, resulting in a brightening and poleward jump of the main oval. Empirical models of the magnetic-field mapping from magnetosphere to ionosphere suggest that the day side oval should brighten more than the night side, and the dawn side more than the dusk side.



Unstable and Periodic Loss of Plasma from the Saturn System Studied using a Global MHD Simulation

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University of Michigan

We present the results of a highly resolved 3D global magnetohydrodynamic (MHD) simulation of the magnetosphere of Saturn with the goal of understanding the patterns of plasma convection in the magnetosphere. Our initial idealized study shows that the magnetosphere may be unstable on a global scale, resulting in periodic releases of plasma that are the main mechanism for large scale plasma loss from the magnetosphere. In our initial study the dipole and rotation axis are aligned along the z-axis perpendicular to the incident plasma flow that contains a Northward Bz IMF. In our initial study plasmoids are released down tail with periods at multiples of the Saturnian rotation rate. In addition, we find that structures of enhanced plasma density develop near the orbit of Titan. These structures are radially narrow but wrap a significant way around Saturn. These “fingers” are possibly reminiscent of the plasma fingers from the Voyager era. Our presentation will explore extended studies of these phenomena.

Mapping the Interaction of Outer Planet Upper Atmospheres with the Atmospheres of their Satellites and Magnetospheres Via Velocity Resolved Emission Line Measurements

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(1) University of Washington
(2) University of Wisconsin

A key to the understanding of the interaction between satellite atmospheres and the magnetospheres and upper atmospheres of the outer planets is the ability to isolate the characteristics of the various species, both neutral and ion at multiple locations in the system. This material plays many roles such as providing conduits for currents to flow to and from the ionosphere of the giant planet, determining the equilibrium volumetric characteristics of the magnetosphere, and driving a supplemental high energy interaction with satellite atmospheres. By obtaining maps of the brightness, volume distributions, and velocity/thermal characteristics of emissions from neutral and charged particles in satellite atmospheres, the planetary corona, and the giant planet's atmosphere, it is possible to trace these interactions and their regions of influence in the magnetosphere. Accurate determination of these parameters requires a combination of high sensitivity, modest spatial sampling, and sufficient spectral resolution to resolve out the ~1-10 km/sec scale velocity structures and ~1000-10000 K temperatures that define the particle motions. Velocity resolved studies have been limited to date by the intrinsically low étendue of high spectral resolution instruments and their large relative size, which have restricted their use to remote sensing investigations from the Earth or Earth orbit. Using examples of model simulations and existing measurements, we will discuss how the general technique of high spectral resolution interferometry could be applied to future exploration of outer planet magnetospheres.

Preliminary Interpretation of Titan Plasma Interaction as Observed by the Cassini Plasma Spectrometer: Comparisons With Voyager 1

R. E. Hartle, **E. C. Sittler, Jr.**, R. E. Johnson, D. G. Simpson, H. T. Smith, F. Crary, D. J. McComas, D. T. Young, A. J. Coates, F. M. Neubauer, S. Bolton, D. Reisenfeld, K. Szego, J. Berthelier, M. Michael, A. Rymer, J. Vippola, J. T. Steinberg, N. Andre

The Cassini Plasma Spectrometer (CAPS) instrument made measurements of Titan's plasma environment when the Cassini Orbiter flew through the moon's plasma wake October 26, 2004 (flyby TA) and December 13, 2004 (flyby TB). Preliminary CAPS ion and electron measurements from these encounters (1, 2) are compared with measurements made by the Voyager I Plasma Science Instrument (PLS). The comparisons are used to evaluate previous interpretations and predictions of the Titan plasma environment that have been made using PLS measurements (3, 4). The plasma wake trajectories of flybys TA, TB and Voyager 1are similar because they occurred when Titan was near Saturn's local noon. These similarities make possible direct, meaningful comparisons between the various plasma wake measurements. The inquiries stimulated by the previous interpretations and predictions made using PLS data have produced the following results from the CAPS ion measurements: A) The major ambient ion components of Saturn's rotating magnetosphere in the vicinity of Titan are H+, H2+, and O+. B) Finite gyroradius effects are apparent in ambient O+ as the result of its interaction with Titan's atmosphere. C) The principal pickup ions are composed of H+, H2+, CH4+ and N2+. D) There is clear evidence of slowing down of the ambient plasma due to pickup ion mass loading; and, as the "ionopause" is approached, heavier pickup ions such as N2+ become dominant. The similarities and differences between the magnitudes and structures of the electron densities and temperatures along the three flyby trajectories are described

1. D. T. Young et al. (2004), Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract P41B-07.
2. A. J. Coates et al. (2004), Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract P53A-1451.
3. R. E. Hartle et al., J. Geophys. Res., 87, 1383, 1982.
4. E. C. Sittler et al., Titan Symposium Proceedings, ESTEC, Editor, Jean-Pierre Lebreton, 2004.

Wave Normal Calculations of Low Frequency Plasma Waves Using the Cassini Radio and Plasma Wave Science Five-Channel Waveform Receiver at Saturn

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The Cassini Radio and Plasma Wave Science (RPWS) investigation is designed to study the radio emissions and plasma waves in the vicinity of Saturn. The RPWS Five-Channel Waveform Receiver (WFR) provides simultaneous waveforms from up to five separate sensors in passbands of either 1 Hz to 26 Hz, or 3 Hz to 2.5 kHz. The wave normal and Poynting vector of the various detected electromagnetic plasma waves can be calculated from the direct measurements of the three-axis magnetic and the two-axis electric wave fields. This analysis is important in determining the polarization, the mode, and the source region of these waves. During the first six passes of the Cassini spacecraft through the inner magnetosphere of Saturn, a variety of low-frequency plasma waves have been observed, including hiss and chorus-like emissions. Poynting vector and wave normal analysis using the Means method are performed on these emissions and compared to similar emissions detected at Earth. For example, initial results show the chorus-like emission detected at Saturn propagates away from the Saturnian magnetic equator, similar to observations of chorus propagation at the Earth.

Interplanetary Conditions and Magnetospheric Dynamics During the Cassini Orbit Insertion Fly-Through of Saturn's Magnetosphere

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We consider observations of the magnetic field and Saturn kilometric radiation (SKR) during the Saturn orbit insertion (SOI) fly-through, and their relation to concurrent conditions in the interplanetary medium. Examination of Cassini interplanetary magnetic field (IMF) data over five solar rotations bracketing the fly-through shows that the phasing of recurrent corotating interaction region (CIR) compressions in the heliosphere is such that one of them is expected to have impinged on Saturn while Cassini was inside the magnetosphere. Magnetic field data before and after the encounter confirm that the expected heliospheric current sheet (HCS) crossing took place while Cassini was inside. The effect of the passage of the 'same' CIR compression six solar rotations earlier was observed by the Hubble Space Telescope (HST) and by Cassini during its approach to the planet at the end of January 2004, and was found to produce major enhancements in UV aurora and SKR emissions. Enhancements in SKR emissions were also observed during subsequent passages of this CIR bracketing the SOI fly-through. Here we show that major bursts of SKR were observed by Cassini on the outbound pass during the SOI fly-through which show considerable similarity to those observed during the January 2004 CIR compression event. In particular, both are associated with extensions to lower frequencies, and both also produce disruptions of the usual SKR modulation at the planetary rotation period. We thus suggest that the bursts observed during the SOI fly-through were associated with an auroral enhancement event of the same nature as observed by the HST at the end of January 2004, produced by the effect of the anticipated CIR compression of the magnetosphere. Simultaneous Cassini measurements of the magnetic field in the nightside magnetosphere indicate the injection of hot plasma at the spacecraft in association with the main SKR burst, which we suggest could have been due to the onset of reconnection in the tail.

Titan's "Induced" Magnetic Tail as Seen by Cassini's Magnetometer

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(2) Institute for Geophysics and Meteorology, University of Cologne

Saturn's largest moon, Titan, is the only moon in the solar system known to have a substantial atmosphere and thus ionosphere. Since Titan's orbit is usually within the Kronian magnetosphere, the moon poses an obstruction to the co-rotating magnetospheric plasma. This causes the magnetic field lines to drape around Titan, giving rise to a magnetic tail. The geometry and structure of this magnetic tail, including the polarity reversal layer and the tail/magnetosphere boundary, as determined by analysing data from Cassini's magnetometer will be discussed. Cassini has made five close flybys of Titan: the first three (TA, TB and T3) all occurred at very similar Saturnian local times (SLT) of late morning and the next two flybys (T4 and T5) both occurred close to dawn SLT. A comparison will also be made to the Voyager flyby, which was early afternoon SLT.

A Comparison of MHD Model Calculations with Observations for the Ta and Tb Flybys of Titan by Cassini.

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We use our 3D, multi-species, high spatial resolution, global MHD model to calculate the plasma parameters (density, temperature, velocity and magnetic field) corresponding to the Ta and Tb flybys of Titan by Cassini. Our model uses a spherical grid structure leading to very good (~36km) altitude resolution in the ionospheric region of Titan. The model also provides good resolution and meaningful results in the upstream and wake regions. Titan's atmosphere/ionosphere is described by10 neutral and 7 ion species. We compare our results with the relevant observations from CAPS, MAG and the Langmuir probe and discuss the potential reasons for the observed agreements and disagreements of this comparison.

The Generation of Ordered Fine Structure in the Radio Emission Observed by Cassini, Galileo, Cluster, and Polar

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Cassini has observed ordered fine structure in the Saturn kilometric radiation (SKR) data that bears a strong resemblance to similar features observed by Polar, Cluster, and Galileo in the terrestrial auroral kilometric radiation (AKR) data. We report the results of an investigation of waves observed by the Cluster wideband instrument (WBD) during an orbital conjunction with the Polar spacecraft. During this perigee pass Polar was at the upper extent of the AKR source region in the southern hemisphere nightside auroral region. Cluster was located at higher altitude above this region and observed AKR with clear signatures of ordered fine structure striations (rain). Using electron particle data observed by HYDRA on board Polar, we have modeled the electron distribution function within the AKR source region. This distribution function is unstable to a number of low-frequency wave modes and supports EMIC waves propagating up the magnetic field line. We investigate the role of these waves in stimulating the growth of AKR and producing the ordered fine structure observed by WBD on board Cluster. We believe this same mechanism may be applicable to the ordered fine structure observed in SKR by Cassini. In addition we report initial results of attempts to simulate this process using a 2-dimensional, electromagnetic, self-consistent, particle-in-cell plasma code.

Implications of rapid planetary rotation for the Dungey magnetotail of Saturn

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Employing our current understanding of the structure and dynamics of Saturn's magnetosphere, we present a time-dependent model of the kronian Dungey cycle magnetotail, based upon a modification of a similar model developed for Earth's magnetotail. The major difference arises due to the rapid rotation of Saturn and the partial corotation that this imposes on the open field lines threading the polar cap. This results in twisted tail lobes, with the form of concentric cylinders of oldest to newest open flux from the inside out. The oldest, and hence longest, open field lines form the backbone of a highly extended magnetotail. Surrounding this are bundles of field lines disconnected by tail reconnection, propagating down-tail at the solar wind speed. Due to the twisted nature of the tail, these bundles remain entangled with the lobe cores to form "exterior flux ropes". In the limit that the addition and removal of open flux from the magnetosphere by magnetic reconnection can be treated as a last-in-first-out system, we formulate a description of the flux transport within the tail, and drive this with estimated dayside reconnection voltages deduced from Cassini observations of the IMF made upstream of Saturn.

Atomic and Molecular Ions in the Corona of Titan

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The first two Titan flybys of Cassini Spacecraft occurred on October 26, and December 13, 2004. The closest approaches were 1174 km and 1192 km, respectively, above the surface of Titan. The geometries of the flybys were rather similar in both the cases, where the closest approach occurred in the wake of the satellite. Cassini plasma spectrometer measured electrons and ions as a function of energy and angle. The plasma flow decreased rapidly to small velocities of the order of a few tens of km s-1 showing large mass loading with ions before entering a region of cold and dense plasma of the ionosphere of Titan. During the outbound the changes were much quicker and the spacecraft left the mass loaded region very rapidly. Measurements of angular and energy distribution of ions species, including CH_4^+ and N_2^+, made by the CAPS instrument near Titan have been used to estimate the ion fluxes impinging on the exobase of Titan. Such ions can efficiently eject neutrals from Titan's atmosphere, a process often called atmospheric sputtering. Using models of the interactions developed earlier (Michael et al. 2005a, b) the effect of these ions on loss and heating of Titan's atmosphere near the exobase will be discussed.

Modelling the Ionospheric Contribution to Saturn's Inner Plasmasphere

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Ion densities from the three-dimensional Saturn-Thermosphere-Ionosphere-Model (STIM, Moore et al., 2004) are extended above the plasma exobase using the formalism of Pierrard and Lemaire (1996, 1998) which evaluates the balance of gravitational, centrifugal and electric forces on plasma in a rotating dipole field. The parameter space of ionospheric contributions to Saturn's inner plasmasphere is explored by comparing results that span the observed extremes of plasma temperature, 650 K to 1700 K, and the range of velocity distribution functions, Lorentzian (or Kappa) to Maxwellian. Calculations are made for plasma densities along the path of the Cassini spacecraft's orbital insertion on 1 July 2004. These calculations neglect any ring or satellite sources of plasma, which are likely minor contributors at 1.3 Saturn radii. There is a wide range of combinations of kappa and plasma temperature that lead to predictions of order 100 electrons / cc at Cassini's closest approach, in some agreement with preliminary results from Cassini (e.g. Gurnett et al., 2005).

Moore, L.E., M. Mendillo, I.C.F. Mueller-Wodarg, and D.L. Murr, Icarus, 503-520, 2004.

Pierrard, V. and J. Lemaire, J. Geophys. Res., 101, 7923-7934, 1996.

Pierrard, V. and J. Lemaire, J. Geohpys., Res., 103, 4117, 1998.

Gurnett et al. (26 co-authors), Science, 307, 1255-1259, 2005.

Study of Specific FUV Auroral Features of Saturn

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In January 2004, FUV images of Saturn have been recorded with the STIS camera on board the Hubble Space Telescope. During the same time, the RPWS instrument on board the Cassini spacecraft, in approach of Saturn, have recorded radio data. We will discuss specific FUV auroral features, their relations to magnetospheric processes and radio emissions.

Comparison of the Earth, Jupiter's and Saturn's Auroral Response to the Same Interplanetary Shock

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We have studied the auroral response of the Earth, Jupiter and Saturn to an interplanetary shock which successively flew past each of the planets. The auroral emissions were monitored by POLAR at Earth, by Galileo and Cassini at Jupiter, and by HST at Saturn. Coordinated measurements in the solar wind near the Earth and Jupiter executed during this period permitted to propagate the shock out to Saturn using an MHD code. We show that the shock retained its ability to trigger planetary auroral responses throughout a large part of the solar system, and we discuss the similarities and differences observed between them.

Statistical analysis of the plasma transition across the bow shock at Saturn.

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The Cassini spacecraft entered Saturn orbit in June 2004 and has made measurements of low energy ions and electrons at unprecedented spatial and temporal resolution. In this presentation we summarise the properties of Saturn's bow shock as observed by the Cassini plasma spectrometer (CAPS) during the first eight orbits of Cassini's tour at Saturn from June 2004 to May 2005. At this time Cassini was within 22 degrees of Saturn's equatorial plane with apoapses in the pre-noon dayside sector. The shock at Saturn is, as expected, a strong shock and hence an effective thermaliser of plasma. We will concentrate on a statistical analysis of the plasma density and temperature transition measured by the CAPS electron spectrometer (CAPS-ELS) across the shock and present analysis of this with respect to upstream conditions, shock location and solar wind magnetosonic Mach number. This is important in understanding how solar wind energy is dissipated across the shock and so how the shock front modifies the plasma which will ultimately impact upon Saturn's magnetosphere. Comparison of the bow shock as observed at Saturn with those of the Earth and Jupiter as observed by the same instrument during the respective planetary flybys will also be discussed.

Multi-Fluid Modelling of Titan's Interaction with Saturn's Magnetosphere

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The interaction of Titan with the energetic particles within Saturn's magnetosphere produces a major loss mechanism for Titan's atmosphere. 3-D multi-fluid models are used to investigate the plasma interaction at Titan with a particular emphasis on dynamics of light and heavy ions from the magnetospheres of Saturn and Titan. Because the gyro-radius of an ion can be a significant fraction of the plasma interaction region around Titan, ion cyclotron effects are very important, particularly for the heavy ions. These effects control the atmospheric loss rate, generate asymmetries in the plasma flows around Titan and modify the magnetic field configuration relative to that predicted by single fluid MHD simulations. We demonstrate the differences in loss rates for different atmospheric scale heights and Saturnian plasma conditions and quantify the resultant changes in Titan's magnetic signature through sample spacecraft flybys.

Cassini RPWS LP Measurements of Cold Plasma Near Titan

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We present results of the cold plasma environment around Titan obtained primarily by the Cassini Radio and Plasma Waves Science (RPWS) Langmuir probe (LP) sensor during the Ta, Tb, T3, T4 and T5 flybys. The data show that magnetospheric conditions play a crucial role for the structure and dynamics deep into the ionosphere of Titan. The electron number density, electron temperature, average ion mass and ion flow characteristics are discussed. The general shape of the ionospheric number density during the flybys can broadly be explained by photo-ionization by UV light from the Sun and magnetospheric electron impact ionization. However, the plasma density was otherwise very structured and could be related to similar features in the magnetic field data. The wake electron temperatures increased with altitude, and were to a large degree consistent with electron heat conduction from the hotter Titan wake. An intriguing result at Ta was the sharp increase in averaged ion mass to 60-70 amu below the maximum number density near closest approach on the less solar illuminated outbound pass. The mass loading boundary (MLB) and ionopause were identified. No large asymmetry of the mass-loading region could be detected between the inbound and outbound during Ta, which was in stark contrast to both the Voyager- 1 flyby characteristics and the Tb flyby cold plasma characteristics. An extensive mass load region on the anti-Saturn side of Titan forms therefore only under certain magnetospheric conditions. The total escape flux was estimated to a few times 10^{25} ions/s.

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